Characterising Space Use and Electricity Consumption in Non-domestic Buildings

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Abstract

Energy used in the operation of the United Kingdom's non-domestic buildings contributes 18% of national carbon dioxide emissions and reducing these is government policy. The use of electrical equipment in buildings is a major contributor to overall consumption, due to both its intrinsic energy consumption and the effects of incidental internal gains resulting from its operation. Knowledge of how and where consumption and internal gains occur in buildings is important in understanding the consumption characteristics of the building stock.

The overall aim of this research was to improve the prediction of energy consumption in the non-domestic stock through the inference of appliance electricity consumption and resultant heat gains, for internal space uses of premises, as identified in UK property taxation data. To achieve this, the objectives were to:

1. Develop a method for inferring space usage in premises.
2. Infer values for the electricity consumption of appliances, and hence internal gains, for space uses within premises.
3. Apply the method to a dataset at the urban scale and use a suitable model to deduce the energy consumption.
4. Compare the results with measured data.

Objectives 1 and 2 were achieved through analyses of detailed energy surveys of more than 300 non-domestic premises. By excluding equipment used for heating and cooling, both intrinsic electricity consumption and internal gains from appliances have been characterised for combinations of internal space use and premises activity type. For each combination, the characteristics include the energy intensity (kWh/m2/year) for:

- overall appliance use
- 14 end uses of appliances (e.g. lighting, catering, computers)
- 18 groups of appliance activity descriptions (e.g. sales, office work, process)

These characteristics were mapped onto subdivisions of space use, within premises, listed in property taxation data for a test urban area (City of Leicester). Using only 115 descriptions of space use, appliance consumption characteristics have been inferred for 91.5% of the measured internal floor area of the test dataset; this achieved the third

objective. More than 80% of the floor area was identified using standard space use descriptions utilised in real estate taxation datasets.

The total estimated consumption accounted for 75% of the recorded annual electricity consumption of the test area (the fourth objective). This result is acceptable, given the known limitations of the datasets and suggests that the method constitutes an improvement to stock energy modelling, thus meeting the overall aim.

By inferring appliance electricity consumption and internal gains at a finer spatial resolution than previous methods, the diversity of energy consumption characteristics of the non-domestic stock may be represented more faithfully than by values applied to entire homogenised premises or premises types. The method may be used by policy makers as part of an urban energy model and as a means of evaluating potential energy interventions in the non-domestic stock, or parts thereof.

Acknowledgements

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At all times, the support and encouragement received from friends has been invaluable. Also, colleagues in the Institute of Energy and Sustainable Development and beyond – too many to mention – have helped focus my work and bring it to fruition. Many of these people acted as sounding boards for my thoughts and spurred me on.

I must also mention my sister Chris, who supported my parents when things got very difficult for them, allowing me to pursue my work. Each member of her family played their valued part, too.

Not least, I am indebted to my mother, for her eternal support. Also, to Chloë, who talked me out of giving up – so at least I have someone to blame.

But, when all is said and done, this work is dedicated to Dad who, sadly, was forced by nature to take the only sure fire route to avoid reading this thesis.

Declaration

During the period of registered study, in which this thesis was prepared, the author has not been registered for any other academic award or qualification.

The material included in this thesis has not been submitted, wholly or in part, for any award or qualification other than that for which it is submitted.

I declare that the contents of this submission are wholly my own work.

Robert G Liddiard. December 2011

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Abbreviations and Acronyms

Abbreviation/Acronym	Description
AUC	Accommodation Use Code
BARefNo	Billing Authority Reference Number
BRE	Building Research Establishment
BS	British Standard
CAD	Computer-Aided Drawing
CaRB	Carbon Reduction in Buildings (project)
CFL	Compact Fluorescent Lamp
CIBSE	Chartered Institution of Building Services Engineers
DCLG	Department for Communities and Local Government
DEC	Display Energy Certificate
DECC	Department for Energy and Climate Change
DEFRA	Department for Environment, Food and Rural affairs
DETR	Department for the Environment, Transport & Regions
DHW	Domestic Hot Water
DUKES	Digest of United Kingdom Energy Statistics
EEO	Energy Efficiency Office
EEP	Energy and Environmental Prediction (model)
EHCS	English House Condition Survey
EHS	English Housing Survey
EI	Energy Intensity (kilowatthours/m^2/year)
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
GEA	Gross External Area
GIA	Gross Internal Area
GIS	Geographical Information System
HMG	Her Majesty's Government (UK government)
HVAC	Heating, Ventilation and Air Conditioning
IPCC	International Panel on Climate Change
ISO	International Organisation for Standardisation
LLPG	Local Land and Property Gazetteer
NDBS	Non-domestic Building Stock
NDCSM	Non-domestic Carbon Scenario Model
NDEEM	Non-domestic Energy and Emissions Model
NEED	Non-domestic Energy Efficiency Data Framework
NHER	National Home Energy Rating
NIA	Net Internal Area
NLPG	National Land and Property Gazetteer
ODPM	Office of the Deputy Prime Minister
OECD	Organisation for Economic Cooperation and Development
ONS	Office of National Statistics
PC	Personal Computer
PD code	Primary Description code
RIBA	Royal Institution of British Architects
RICS	Royal Institution of Chartered Surveyors
RL	Rating List (database)
RV	Rateable Value

SCAT	Special Category (code)
SHU	Sheffield Hallam University
SMV	Summary Valuation (database)
TH	Tungsten Halogen (lamp)
TOID	Topographical Identifier
UK	United Kingdom
VOA	Valuation Office Agency

Chapter 1: Introduction

> *"An energy audit, however imprecise, should be undertaken early in any energy efficiency programme to identify where energy is being used. It is then possible to direct energy efficiency action towards the highest consumers."*
>
> (Jones, 2004, page 18-2)

Jones, above, is describing what should be done for an individual building, but the same is true when addressing the energy consumption of building stocks (Bruhns, 2008).

Understanding how the United Kingdom (UK) building stock consumes energy will play a key role in the formulation of effective policies to reduce emissions from the built environment (Penman, 2000). This thesis aims to add to the understanding of energy use in the UK non-domestic building stock, through a characterisation of its internal spaces and their electricity consumption.

This introduction lays out the motivation, background, and need for this research. The chapter concludes with the research aims, objectives and novelty and an outline of the thesis structure.

1.1 Motivation

In 2008, the UK government committed itself to delivering an 80% reduction in total UK carbon emissions by 2050, using 1990 as the baseline year (HMG, 2008). This is an ambitious target and there is an interim target that there be a 34% cut in emissions by 2020. These targets are a response to the now widely accepted phenomenon of global climate change and the part played in this by anthropogenic carbon dioxide (CO_2) emissions resulting from the combustion of fossil fuels (IPCC, 2007). A further driver, in the UK, is concern over the security of energy supplies (DECC, 2010a).

Buildings are responsible for 45% of total UK carbon emissions (UK Green Building Council, 2011a, 2011b), so for the government to achieve its 2050 target, emissions from buildings must be cut. As 18% of UK carbon emissions result from the operation of non-domestic buildings (UK Green Building Council, 2011b) and it is not reasonable to completely remove carbon emissions from every other UK source, it is appropriate to assume that emissions from the non-domestic building stock must form part of these reductions. To enable management of energy consumption and to achieve emissions reductions in the stock, government, planning bodies and other relevant organisations will benefit from a sound understanding of the building stock and its operational characteristics (Penman, 2000, Neffendorf et al., 2009), but levels of understanding of the characteristics of the UK's building stock are mixed.

The domestic building stock is made up of houses, apartments and so forth and it has one fundamental use, as dwellings. The domestic stock is also limited in its range of built forms (Firth et al., 2009) and its energy consumption has been the subject of much research. Conversely, the non-domestic stock is made up of all buildings that are not dwellings, such as offices, hospitals, factories and schools and is consequently extremely diverse in both its activities and its built forms. The non-domestic stock, for all its diversity, has not been studied to the same extent as the domestic stock (Steadman et al., 2000b).

1.2 The Significance of the Non-domestic Building Stock

In the UK, the rate of building construction is only 1–2% per year (Ravetz, 2008) and approximately 70% of the current UK non-domestic stock will still exist in 2050, so most of the buildings of the near and medium-term future already exist (UK-GBC, 2007). Furthermore, it has been suggested that due to the current economic downturn, the rate of construction may be even lower (Griffiths, 2009), leading to a slower turnover of stock. These considerations place an emphasis on addressing the energy consumption of existing buildings, as it is not feasible to achieve large stock emissions reductions from new buildings alone, even if they have zero emissions. Awareness of this situation is not limited to the UK and it is recognised, at the global level, that the mature building stock of the developed world presents good potential for emissions reductions (OECD, 2004).

In 1965, the UK government began central regulation of building standards, but it was not until 1972 that non-domestic buildings were subjected to regulations that affected their energy performance (HMG, 1965, HMG, 1972). The first major regulation of the energy performance of non-domestic buildings came in 1985, with the introduction of the Building Regulations, Part L Conservation of Fuel and Power (HMG, 1985).

Subsequent updates to these regulations have gradually called for improvements to energy performance. Some local councils also stipulate additional requirements that are designed to reduce the carbon dioxide emissions of buildings, for example the Merton Rule (Merton, 2009). However, such regulations tend only to affect new buildings and major refurbishments of existing buildings, so their impacts are reduced by low rates of construction and refurbishment. Also, some buildings, accounting for more than 60% of the stock floorspace, were built before the 1985 Building Regulations' requirements to manage energy consumption (DCLG, 2005b, DCLG, 2005a). In building stock modelling, it is generally assumed that buildings are constructed to the minimum level of performance required to meet contemporary regulations (Wright, 2005). If these buildings have remained largely unmodified they may be, as yet, unaffected by energy-related building regulations, representing a portion of the stock with high potential for emissions reductions.

Although the rate of stock turnover is low, as a proportion of the total stock, the rate of change of activity within buildings is less slow. Evidence of change can be seen in the reuse of buildings for activities for which they were not originally designed; for example, old factory and warehouse buildings converted to office use. In some cases domestic properties have been converted to non-domestic uses.

Where a change of use occurs, the fabric of the building may be left unchanged, as might the building services (heating and domestic hot water systems and suchlike). However, the use of internal spaces, and/or their proportional spatial distribution, may alter to suit the needs of the new overall activity and equipment could also drive the change in how space is used. If this is the case, it is likely that there will be a concomitant change of equipment in the space. For example, converting a retail area into an office area is likely to involve a decrease in display lighting and an increase in computers. The change in space activity and electrical equipment will change the character of electricity consumption of the building. But, with a resultant change in internal heat gains, the operation of the building heating, ventilation and air conditioning (HVAC) systems should also change, as they are adapted to the new internal temperature load profile (Chvatal and Corvacho, 2009, Jenkins, 2009).

Changes in HVAC operation are likely to change overall carbon dioxide emissions. Consequently, it may be assumed that the energy consumption of similar or, in fact, the same buildings may change due to changes in activity and that some changes may be quite subtle. Changes to the mix of types of space and their relative areas within the total area of buildings are likely to have an impact on the energy consumption and CO_2 emissions from buildings.

1.3 Describing and Recording the Building Stock

The Valuation Office Agency (VOA) collects data, on behalf of Her Majesty's Revenue and Customs, for the purpose of placing a taxable value on buildings and land. The VOA generates valuations for hereditaments, known more colloquially as premises, which are a piece of real estate that can change ownership. Premises and the relationship between premises and buildings are explained fully in Section 2.1.5.

The VOA surveys include a classification of overall use, but also often an additional simple breakdown of how space is used within the premises. These subdivisions are called Line Entries. The VOA surveys are not conducted at regular intervals, but they provide data on most of the stock and can be used for modelling. Also, as they are used for taxation purposes it is reasonable to assume that the data are reasonably up-to-date, due to their financial importance to both the premises occupier and government revenue. For this thesis, the VOA Line Entries data are the source of current information on the use of space within premises.

The only major survey of the built form of the UK non-domestic building stock was carried out between 1989 and 1992 (Brown et al., 2000), as a component of the national Non-domestic Building Stock (NDBS) database. The database was designed to improve recording and place the understanding of the stock on a more sound statistical foundation, with the further intention that there be periodic updating of the database. However, there have been no further major surveys of built form and the NDBS remains the most important source of such information.

Parallel to, but not concurrent with, the external building surveys carried out for the NDBS project, a large number of detailed energy surveys were carried out on (mostly) a subset of the same Four Towns buildings, by the Resources Research Unit of Sheffield Hallam University (SHU) (Mortimer et al., 2000a). These surveys are the only accessible large-scale investigation of and dataset for non-domestic building energy consumption characteristics for the UK stock. The surveys were carried out between 1992 and 2000 and are described in detail in Chapter 3.

1.4 Energy Consumption Data for the Building Stock

For England and Wales, the Department for Energy and Climate Change (DECC) makes accessible tables of consumption, by fuel type, down to Local Authority level (DECC, 2010b, DECC, 2010c). However, these data do not reveal the activities that consume the energy, merely dividing consumption into either domestic, or non-domestic and industrial. So, at this level of aggregation it is not possible to determine the consumption of individual buildings, building activity types, what the energy has been used for, or other levels of detail useful for policy development.

Some sources of information, relevant to energy consumption and the analysis of its characteristics, such as the Energy Performance Certificate (EPC) (DCLG, 2008c) and the Display Energy Certificate (DEC) (DCLG, 2008a) exist for individual buildings; however, these are not yet publicly accessible for all building types. EPCs should be available to potential lessees and purchasers of real estate, whilst the principal information in DECs is accessible but only for buildings that are open to the public and >1000m^2. In contrast to these specific potential sources of information, there is a general lack of collection of publically-accessible data about the characteristics of energy consumption in the non-domestic stock. This situation is in stark contrast to the domestic stock, which is the subject of a randomised survey of approximately 8,000 dwellings each year, as part of the English Housing Survey (DCLG, 2009).

In the absence of sufficient readily-usable and useful data, at a level of adequate detail, it becomes necessary to model the stock's energy consumption.

1.5 Modelling Energy Consumption

Energy consumption models for individual buildings generally require levels of data that are not practical or economical to collect for large numbers of non-domestic buildings (UK-GBC, 2007). Multi-building models need to be based on data inputs capable of providing a robust and computationally practicable methodology, giving results with an acceptable degree of accuracy (Robinson et al., 2009). And, in the absence of individual building surveys, these data inputs will be governed ultimately by access to suitable sources of mass data (Thuvander, 2002). Where data are difficult to access, or are sometimes inaccessible, it is generally acceptable to infer input values for a model, basing the inferences on relationships to other data that are both appropriate and accessible. For example, thermal performance of building envelopes may be inferred from the age of a building, due to the influence of building regulations (Smith, 2009). These other sources of data should have a robust and verifiable provenance.

Several models exist for this purpose, using a suitably limited range of inputs (Pout, 2000, Jones et al., 2000, Bruhns et al., 2006, Hinnells et al., 2008). These models operate at varying resolutions from the entire UK stock, down to the post code level of around 15 addresses (Royal Mail, 2003). Fuller descriptions of these models can be found in Chapter 2.

It is the intention of this thesis to investigate the role of space use within premises and how this may be used in non-domestic stock energy modelling. This involves analysing the SHU energy surveys to characterise the electricity consumption of space uses within non-domestic premises. Analysis is restricted to what will henceforth be termed “appliances”. These appliances consist of electrical devices such as lighting, computers, catering equipment and so forth. Devices that generate warmth or coolth, for the temperature control of spaces in buildings, are excluded. A fuller explanation is given in Chapter 3. The characteristics identified within the SHU data are then mapped onto a test urban area scale sample of VOA data Line Entries.

Through the analysis of the consumption of appliances, values for the incidental internal heat gains of spaces can be identified and categorised according to the use of the space and end use of the electricity consumed. These internal gains values may then be used to infer values for premises and buildings in a stock energy and emissions model, based on Line Entries from VOA premises records.

1.6 Research Need

For the government to meet its target of an 80% cut in the UK’s carbon dioxide emissions, by 2050, and with 18% of current emissions (UK Green Building Council, 2011b) coming from the non-domestic building stock, it is clear that the stock’s emissions must be cut substantially.

The 445TWh of energy consumed by the domestic building stock of England and Wales (ONS, 2010) is spread across 21.6 million households, equating to 20,600kWh per household (ONS, 2001) and there is a relative wealth of data about the characteristics of this stock. The 300TWh of consumption of the UK's non-domestic buildings is spread across 1.8 million premises, equating to 187,500kWh per premises (DCLG, 2010c), about which there is relatively little information. From this it might be said that for the domestic stock there is a great deal of understanding about a large number of small individual energy consumers, but for the non-domestic stock there is limited understanding of a small number of much larger energy consumers. This implies that well-targeted, but in themselves, small alterations to the non-domestic stock might produce major benefits in energy consumption and reduction in CO_2 emissions. Such alterations to energy consumption in the small number of buildings that make up the non-domestic stock ought to have a much larger overall effect than a similar alteration in the same number of domestic households.

However, the implications of the current lack of collection of, and access to, data are that, without knowing the make up of the stock, policy and planning decisions are based on very limited empirical evidence. Equally, without direct knowledge, or an empirically-founded model, of what is consuming energy now and how that energy is consumed, it is not reasonable to generate accurate predictions of the effects of interventions, or have meaningful quantification of any effects that occur. Information about non-domestic energy characteristics are scarce, so the modelling of energy consumption is required.

Bruhns (2008) calls for an increase in the understanding of the non-domestic stock, so that policies and interventions may be based upon empirical evidence, thus increasing the likelihood of their effectiveness. Bruhns (2000) has previously identified that the subdivision of premises within Valuation Office Agency data has not yet been analysed, or classified, and that this represents a gap in our understanding of the non-domestic building stock of the UK. By providing a method for identifying and categorising these spatial divisions, an increased degree of detail may be added to stock energy and emissions models, using VOA data.

1.7 Research Aim and Objectives

Overall Aim:

To improve the prediction of energy consumption in the non-domestic building stock by developing a method to infer the electricity consumption of appliances, and resultant incidental heat gains, for the internal space uses of premises, as identified in UK property taxation data.

Objectives:

1. Develop a method for inferring space usage from accessible building and premises data.
2. Infer values for the electricity consumption of appliances, and hence internal gains, for space uses within premises.
3. Apply the method to a dataset at the urban scale and use a suitable model to deduce the energy consumption.
4. Compare the results with measured data.

1.8 Novelty

Previous work has been able to provide estimates of fossil fuel and electricity consumption of multiple non-domestic buildings and/or premises. There have also been breakdowns of energy consumption, by end use, by premises activity type.

This thesis describes a method for estimating the end use electricity consumption, and hence internal gains, of appliances for activity subdivisions within UK premises. The identification of these activity subdivisions and their floor areas do not require a survey by the user of the method, as the base data can be obtained from the UK Valuation Office Agency.

By disaggregating the floor area of premises into categories of space use and by disaggregating appliance electricity consumption within those categories into end uses, a more detailed picture of patterns of energy consumption in the non-domestic stock can emerge.

1.9 Structure of this Thesis

Chapter 2. Describing the Building Stock and Quantifying its Energy Consumption

This chapter gives a description of the state-of-play of how the UK non-domestic building stock is described and modelled, with relevance to multiple building energy estimations.

Chapter 3. The Sheffield Hallam University Data

An introduction to the Sheffield Hallam University (SHU) energy survey data and description of how the SHU database has been used as the source of appliance electricity consumption characteristics, in this work.

Chapter 4. Inferring Energy Characteristics of Non-domestic Premises in Leicester

How the Valuation Office Agency (VOA) data were prepared for use in the space use analysis of a test urban area. The method of applying the outputs of Chapter 3, to provide characterisations of internal spaces and their electricity consumption and internal gains, is described.

Chapter 5. Results and Discussion

This chapter lays out and discusses the results from the implementation of the appliance electricity consumption/internal gains estimation method and the results' comparison with known values of consumption for the test urban area.

Chapter 6. Conclusions

The final chapter is structured according to: the achievements of the research; its limitations; how these may be addressed through further work; and recommendations that would enable the further work and the enhancement of the wider field of study.

Chapter 2: Describing the Building Stock and Quantifying its Energy Consumption

This chapter gives an overview of how buildings are described, how their energy consumption is quantified and how the data are made available as information. Significant issues surrounding the distinction between buildings and premises are also raised and how these affect energy consumption models. In general parlance, the term "building" is frequently used when it is inappropriate; this is particularly the case when dealing with energy consumption. The case is put, later, that buildings are the unit of construction but premises are the unit of operation.

2.1 Buildings and the Building Stock

It is important to recognise and understand the relationship and differences between individual buildings and the building stock, in terms of operational energy consumption and its modelling. An individual building generally has an easily defined system boundary and the characteristics of the building within that boundary can also be defined quite precisely. A building stock is made up of all the buildings within a specified system boundary. A building stock's system boundary is usually defined by a geographical or administrative unit. These include, for example, national and government regions, cities and subdivisions of local authority administrative areas. Within such boundaries individual building types, classified by physical form or activity, can be studied. In some cases, buildings connected to particular economic activities may be studied.

In spite of its complexity, the building stock can generally be separated into two fundamental use classes and one mixed-use class:

- Domestic buildings, for this research, are defined as those that contain households. The Chambers Dictionary (2000) defines a household as, "Those who are held together in the same house, and compose a family: a single person living alone or a group of people living together." For this research, "house" will also mean flat, apartment, or similar dwelling, as described by Bruhns et al (2000, page 642).

- Non-domestic buildings do not contain households and thus follow the definition given by Bruhns et al (2000, page 642). This means that residential care homes, hotels, prisons, detention centres and so forth are defined as non-domestic buildings, even though people live in them. Buildings that house activities in the public and commercial sectors are both included as non-domestic.
- Mixed-use buildings contain both non-domestic and domestic activities, for example a shop with living accommodation above it. The two activities share the same building, but constitute two separate and distinct areas of activity.

This research deals only with the non-domestic and mixed-use building stock. The latter is included to the extent that the building contains some non-residential activity. Areas of mixed-use buildings that are given over to non-residential activities will be described as non-domestic in this research.

2.1.1 Diversity of the Non-domestic Stock

The non-domestic building stock has extreme diversity in its characteristics. Not only are there many built forms, there are also many activities and modes of operation. This contrasts with the domestic stock, which predominantly has a single activity, with similar patterns of activity. Even within the domestic stock, with its relatively uniform patterns of use, the spread of energy consumption is large and prediction can be a complex process.

It is usually the case that an individual building is designed to have a cohesive combination of systems that enable the building to be operated to the greatest effect (Mansfield, 2009). As the building has been designed as a single unit, the system boundary of the building is very clear and information about it can be gathered, in detail, and modelled with relative ease. Also, the design of an individual building can be ascertained by studying it in isolation from other buildings. The building stock has not been designed as a single unit of either construction, or operation, so energy consumption modelling of the stock covers many more combinations of variables than a single building. Small parts of the stock may have been designed and built with shared systems, for example a district heating system, but even this is only for a small number of buildings (in terms of the stock) and these buildings may have very different activities happening in them, making estimations of energy consumption problematic.

Significant insights into the energy consumption characteristics of buildings can be gained from studying individual buildings in operation and a great deal of research is carried out in this area, for example Bordass et al (2001). However, the building stock has not been studied to the same extent, or level of detail. Historically, the domestic stock has been the subject of a major sampling study, called the English House Condition Survey (EHCS), and from 2008 this has been merged with the Survey of English Housing to create the English Housing Survey (EHS) (DCLG, 2009). The UK non-domestic building stock has had no equivalent to the EHCS, or the current EHS.

Variations in the construction of buildings, or the overall style of buildings, may be numerous for a given building activity, due to modes of construction and styles contemporary at the time of construction. Older buildings are more likely to house an activity other than that for which they were originally designed; for example, an 18th Century mill converted to offices or retail.

Within each overall activity, there may be further differences in hours of operation, number of occupants, the types of goods sold or the services provided, each of which are likely to have an effect on energy consumption. Furthermore, each of these operational conditions can be affected by the nature of the organisation occupying a building, which can determine the type of appliances in a building and the level of investment in energy efficiency equipment and practices. The variation is immense. Pout (2000) sums up the degree of diversity in the non-domestic stock by saying that a domestic stock energy and emissions model (Shorrock and Dunster, 1997) can operate with approximately 1,000 building types, but a non-domestic stock model would need 1,000,000 building types to represent non-domestic diversity at a similar resolution.

Yamaguchi et al (2007, page 585) summarise the variability of buildings' characteristics, affecting energy consumption, as being due to:

- *"Size and configuration (shape, zoning adopted) of buildings, which affect the thermodynamic characteristics of buildings and efficiencies of heat distribution systems;*

- *Adopted energy saving measures and heat source systems, which generally depend on the size and usage of buildings;*
- *Usage of spaces in buildings, which determines the scale and pattern of heat gains and electricity loads from spaces and operation hours of HVAC systems."*

In the UK, a considerable proportion of the building stock is quite old, so the age range presents further diversity in built form. Indeed, as regions of the UK underwent urban development over a range of periods, the age of the stock varies across the country (Figure 2.1), so the longevity of buildings can be assumed to vary between regions.

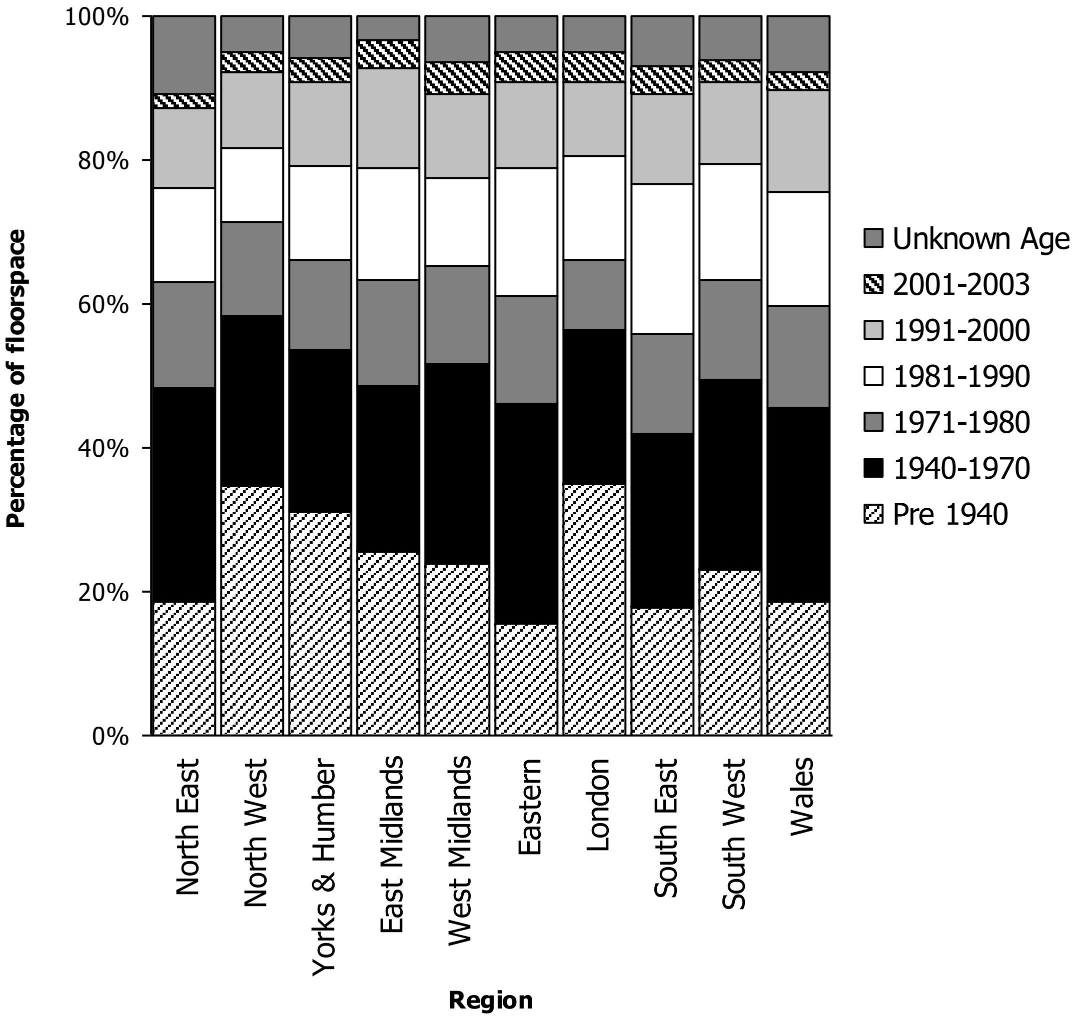


Figure 2.1: Age of non-domestic premises floorspace, by region.
(Source: (DCLG, 2005b)

However, it is also the case that with modern building methods and with some companies owning extensive property portfolios, there can sometimes be standardisation of characteristics; for example in the design of large shed-like buildings used for warehousing and distribution of goods (ProLogis, 2009). Although such buildings may constitute large areas individually, they are less likely to be numerous in a standardised form within the wider stock. So, although there are pockets of standardisation, the non-domestic stock is extremely heterogeneous.

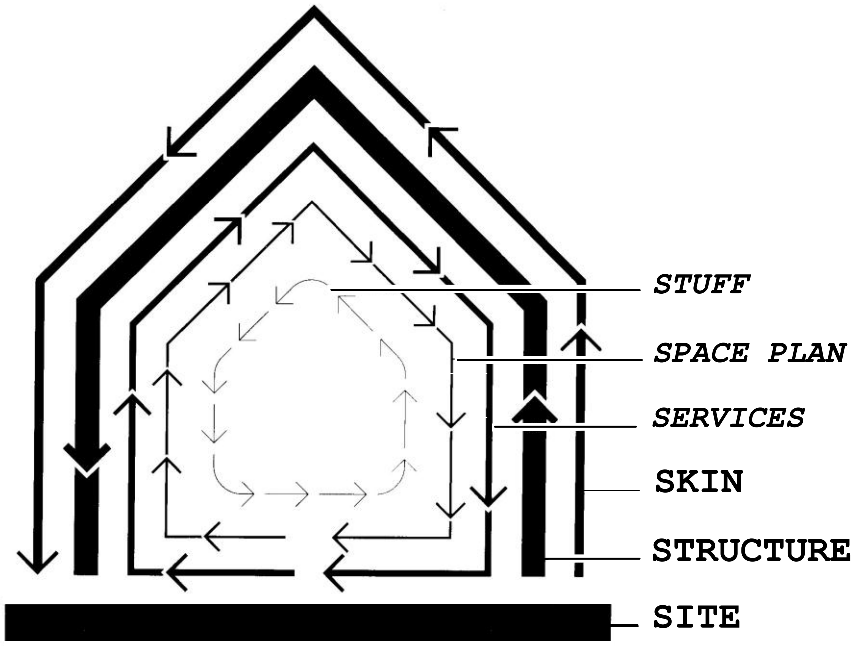
2.1.2 Change in the Stock

Over time, the building stock changes, both in its physical characteristics (built form, services etc) and use characteristics (activity and occupancy etc), but currently in the UK these changes are not systematically recorded with the intention of understanding the stock’s energy consumption, how it has changed, or how it might change in the future.

The use of a model of change aids understanding of how buildings and premises change over time. A model also helps with the prioritisation of data collection, when surveying, describing, recording and categorising the stock’s characteristics and how they change over time. For this thesis, the model described below has proved beneficial.

2.1.3 A Model of Change in Buildings

Duffy describes how a building may be analysed as a set of life cycles: Shell (structure); Services (plumbing, cabling, elevators etc); Scenery (partitions, false ceilings etc); Set (furniture and non-fixed equipment) (Duffy, 1990). Subsequently, Brand (1994) has taken Duffy’s four life cycles and developed the model of building change shown in Figure 2.2, below.



SMALL ARROWS (FAST CHANGE)	
Layers that change — *STUFF:*	The ephemeral contents of the building – that which the occupants bring with them – for example furniture and computers. These characteristics can change easily and quickly.
SPACE PLAN:	The internal layout of the building, including (mostly) non-structural walls/floors*, doors, partitions etc.
SERVICES:	The services are fixed into the internal spaces, or may be embedded, within the building and are problematic to change.
SKIN:	Also called the façade: may change due to building fashions, but unlikely to be changed more frequently than every 20-30 years.
STRUCTURE:	Unlikely to be altered as it is the basic fabric of the construction. Alteration usually entails demolition, thus change is very slow.
LARGE ARROWS (SLOW CHANGE)	
SITE:	The area of land on which the building rests: change is rare.

Figure 2.2: Shearing Layers of Change.

Adapted from Brand (1994, page 13) * Brand does not make it clear whether walls are structural or non-structural.

Brand's model is divided into six layers of physical characteristics – the shearing layers of change. Five of these layers are generally subject to change, with the size of arrows indicating the rate of change. The Site layer has no arrow because it is unlikely to change, as it is a legally defined area, bounded by other adjacent sites. This may be a point of contention, as once a building has been demolished, its site may be partitioned and sold-off piecemeal, limiting what can be built on it. Alternatively, contiguous plots of land might be amalgamated. Brand gives a good example of a series of alterations to a retail building, then its demolition, followed by a completely new structure (Brand, 1994, pages 76-77). The series of changes demonstrates amalgamation of a number of buildings into a single commercial entity, rather than partition. The overall site remains the same, with alterations constrained by the surrounding streets, as is the new building.

In terms of the rate of change, the "slow" elements of the building dominate the "quick" elements, due to a form of inertia (Brand, 1994, page 17). This means that the Site and Structure layers will dominate the inner layers of the building. But this is only the case in terms of physical presence and longevity, not energy consumption. This time-based classification of the elements that make up a building provides an alternative to the more commonly used activity-based models, when describing the characteristics of a building. The time-based classification would also suggest a hierarchy of characteristics to record when surveying buildings. For long term policy/management decisions, the Site, Structure and Skin should be evaluated. For the medium and short term, the Services, Space Plans and Stuff should be analysed.

To engage with the human behavioural factors that affect buildings, Brand suggests an additional layer, which he terms "Souls". However, the suggestion is that humans are dominated by Stuff. In terms of energy consumption related to activities, this is the case, because it is the Stuff within the Space Plan, plus the Services, that consume energy. It is not necessary for people to be in place for the equipment to be using energy; for example, lights left on over night.

In terms of the rate of change, within the lifespan of a building, the people who use it are the most changeable characteristic; for example, as they move around the interior of the building. This is the result of the many influences that act upon the behaviour of humans and can change in a time frame of minutes. Such influences may not all be due to the Stuff in a building, but may be due to human factors such as illness, mood, relationships to/with other occupants, organisational structures, communications, age and so forth. Additionally, patterns of occupation generally have a marked effect upon the energy consumption of buildings, as demonstrated by occupancy factors being applied to energy benchmarks (Field, 2008). However, it is still the case that it is the equipment (Stuff) that consumes energy in a space, not the people (Souls).

2.1.4 Layers of Access to Data

In Figure 2.2, above, it will be noticed that the layer labels, to the right of the graphic, are in standard or italic text. This distinction is an incremental refinement of Brand's model to denote how the Site, Skin and Structure layers (in non-italic text) can generally be determined from outside the building, whereas the inner layers, Services, Space Use and Stuff (italics) can only be accessed from inside the building, or through access to a relevant source of this information.

The availability of data and the costs involved in collecting them are key to defining the data that can be collected for energy consumption models designed for existing buildings. In theory, it is possible to collect all the data that is "achievable" (Thuvander, 2002, page 135) – see Figure 2.3, below. However, Thuvander has identified that, for the building stock, data have a number of layers that affect what can actually be used in a model.

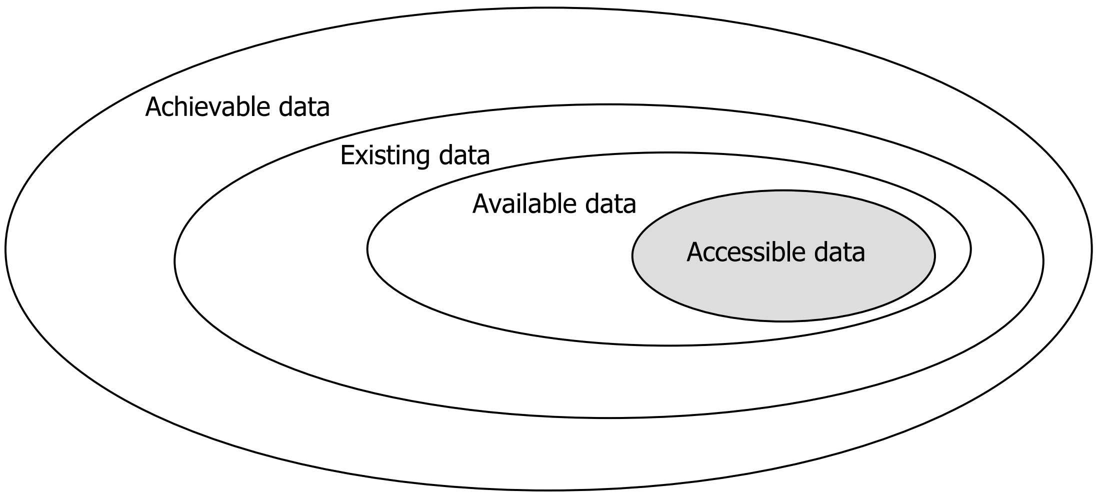


Figure 2.3: Layers restricting data that can be used for models of existing buildings

(Adapted from Thuvander 2002, page 135)

In Figure 2.3, "achievable data" are those which it is possible to generate. "Existing data" have been generated. "Available data" are data that exist but may not be accessible due to strictures such as commercial confidentiality. "Accessible data" are the data that are physically accessible, in a format compatible with the model and can be collected within the operational constraints of the model.

For an energy model, operating at the building design stage, it is possible (though very unlikely) to amass all the achievable data, but for existing buildings, models are limited to accessible data and these may be very few in total number and data type.

2.1.5 Buildings versus Premises

So far, the building stock has been described purely as "buildings", but there is a further complication, or refinement, when describing the stock.

A potential cause of confusion, or at least misunderstanding, is the misuse of the terms "building" and "premises". This problem of defining premises versus buildings is caused by both a legal aspect and a practical aspect of the design and use of buildings.

The Chambers Dictionary definition of a building is:

> n **building**…a substantial structure for giving shelter, eg a house, office-block (Chambers Dictionary, 1998, page 209)

The Chambers Dictionary definition of premises is:

> **Premise**; […] (*usu* in *pl*) the matter set forth at the beginning of a deed (*law*); (in *pl*) the beginning of a deed setting-forth its subject matter (*law*); (in *pl*) the aforesaid (property; *law*); hence, a building and its adjuncts, *esp* a public house or place of business; (Chambers Dictionary, 1998, page 1296)

In UK real estate taxation terminology, premises are called "hereditaments". The Chambers Dictionary definition of a hereditament is:

> *n* **hereditament** any property that may pass to an heir.
> (Chambers Dictionary, 1998, page 750)

Thus premises, or hereditaments, are a piece of real estate which may change ownership as a single unit, whereas a building is primarily a structural form which may be premises, or a number of premises. To increase the complexity of the relationship, more than one building, or portions of a number of buildings, may constitute premises.

Although there are instances of the terms building and premises within the domestic sector – for example a single apartment may be premises, but not a whole building – the issue of the apparent interchangeability of the terms "building" and "premises" is of greater significance in the non-domestic sector. In general usage, it is more common for premises to be called buildings than vice versa.

For this thesis, a "building" means the physical construction, whilst "premises" means the unit of operation of an activity; such as "office premises" being a place where the overall activity may be classed as office work.

2.1.6 Construction versus Operation

Research and general literature tend to refer to buildings of a particular type. For example, "*A steady move from an industrial economy to a service economy meaning reduced factories, more offices and other service buildings*." (Hinnells et al., 2008, page 3.2). This statement of a scenario implies that the buildings are changing. However, in the short to medium term, this is unlikely to be a full explanation of events, due to the low turnover of building stock in the UK (Ravetz, 2008), suggesting that some of the buildings undergo a change of use.

Figure 2.4 and Figure 2.5, below, show the change in the distribution of the Bulk Classes of hereditaments (premises), in recent years, for England and Wales (see Section 4.2, for an explanation of Bulk Classes). It may be observed that factories have declined, proportionately, in both number and floorspace.

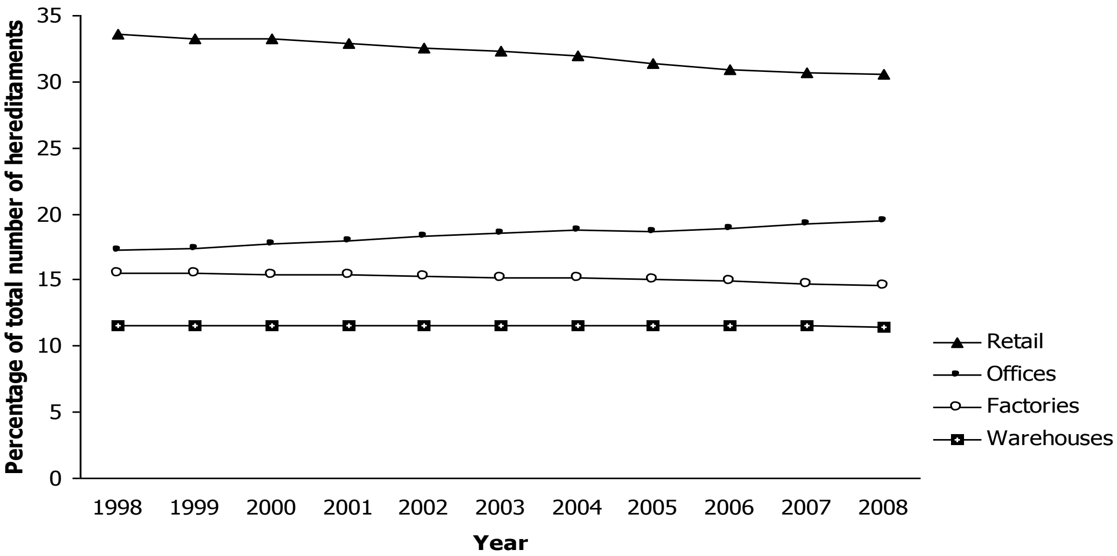


Figure 2.4: Change in distribution of hereditaments, by Bulk Class, 1998 - 2008.

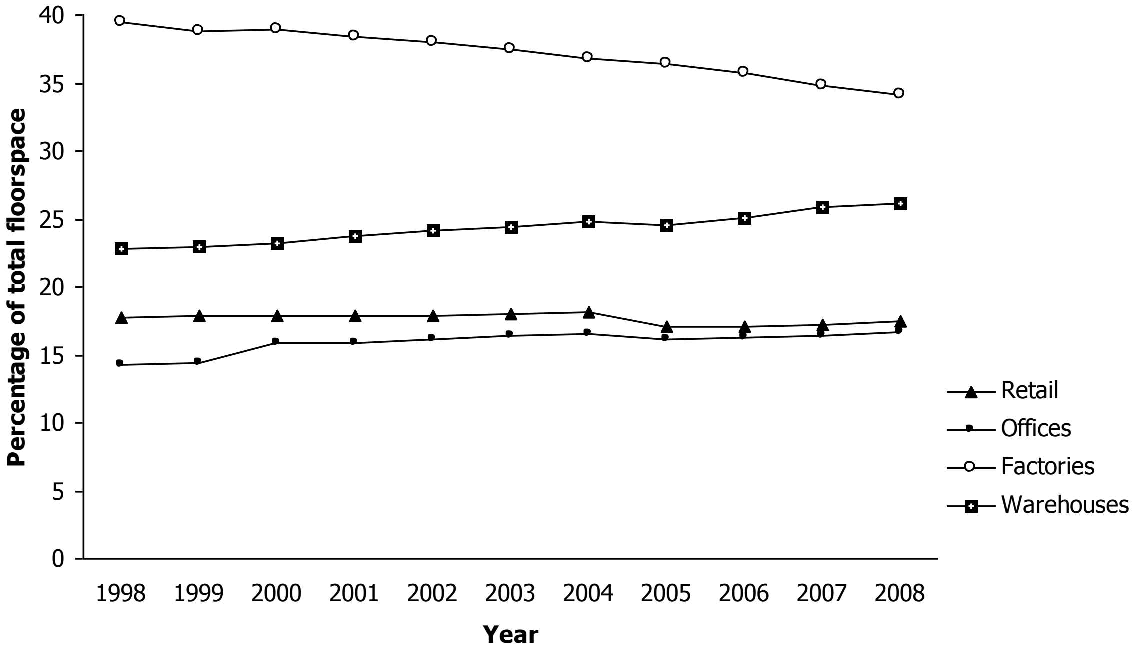


Figure 2.5: Change in distribution of floorspace, by Bulk Class, 1998 - 2008.

It is probable that for buildings that undergo a change of use, their major physical characteristics may remain largely unchanged. However, the classification of the premises will be definitively changed, because the use of the premises has changed and it is their use that defines the classification of the premises. This demonstrates the importance of distinguishing between premises and buildings and that it is the uses of premises that effectively define the building type, as the term "building" is used generically, in most instances.

This need to distinguish between buildings and premises can be strengthened by making the assertion that buildings are the unit of construction and demolition, whilst premises are the unit of operation. This statement fits well with Brand's model of change, as premises are more closely linked to the inner layers of Services, Space Plan, and Stuff, whilst the physical building is mostly the outer layers of Site, Structure and Skin – the elements that are least changeable and defined at the point of construction. This situation may be seen in the design and construction style known as "shell and core". Here the structure and outer fabric of the building are constructed, together with the basic service systems, but tenants are responsible for the fitting-out of their own areas to suit the needs of their activities.

A similar situation arises in industrial property, where a simple portal frame-type building is constructed and the new owner/tenant installs heating, ventilation and air conditioning (HVAC) equipment to suit their needs. Where buildings are filled with equipment that emits high internal gains, the HVAC systems may be used predominantly to extract heat from the building.

It is sometimes the case that multiple premises will share a single building envelope and HVAC systems that are required to meet the needs of each premises occupier. Where an HVAC system has been designed to deal with this multiple use profile, the effect of having differing usage amongst the premises may not be problematic. But where the building and HVAC system were not originally designed for this situation, the overall building energy interactions can become complex and difficult to manage efficiently. The divergence between the construction design and operational characteristics may be large.

Where premises are made up of multiple buildings, such as a university campus, or a large factory complex, the overall premises may fall under one overarching description, but the sum of characteristics of individual buildings may be large, making overall building complexity great, within the premises.

Adding the Souls layer, from Brand's model of change (Section 2.1.3), mostly reinforces premises as the unit of operation, in terms of energy consumption characteristics, as the majority of premises rely on people to cause equipment to use energy. There are, however, some premises that do not have a Souls element, such as advertising rights, or communications masts, but these do not constitute buildings, as such. There are premises without buildings that do have a Souls element, but consume energy, such as floodlit car parks, recreation grounds and storage land.

Further evidence that energy consumption is tied more-closely to premises than to buildings is provided by the nature of energy metering. In the domestic sector, the equivalent of premises is a dwelling. Generally, in the UK, a dwelling will have a billing meter for each energy utility. Even where there are multiple dwellings in a building, generally there will still be a separate meter for each dwelling. In the non-domestic sector, this is also the case for premises in buildings. So, the measurement of energy is generally carried out at the dwelling/premises level, for billing purposes.

From this, it can be argued that, in terms of energy consumption management and particularly interventions, the premises and their operator are the unit of interaction and engagement. The designer and constructor of the building in which the premises are located are not usually relevant in terms of the energy management of the premises, assuming that all measures to ensure the efficient operation of the building have been carried out, prior to the handing over of the building to its occupants. Also, as buildings age, it is increasingly unlikely that there will be any connection between designer/constructor and premises operator. A possible exception would be premises built and operated under a Public Finance Initiative.

2.1.7 Buildings and Premises and their Effect on Energy Modelling

An energy model should be applicable to premises, or buildings, or both. Although a building may be built and operated as one premises, it is commonplace for a single building to be designed and subdivided into a number of premises for letting. Common examples of this are speculative office buildings or contiguous small industrial units. The juxtaposition of these premises can have an effect on the energy consumption characteristics of each premises and the building as a whole. For example, one floor (a single premises) of an office building being empty, might act as a heat/coolth sink for the occupied floors above and below. Thus, the relationship of premises to buildings, in terms of their energy consumption characteristics, should where possible, be identified within any multi-building/multi-premises energy model.

Buildings that are subdivided into premises can have very different activities being performed in different areas of the building. For example, a building with retail premises on the ground floor (perhaps with storage space in the basement), separate office premises on the first floor and a residential apartment on the second floor, such as one might find in a town centre. A representation of this type of building is shown in Figure 2.6, below.

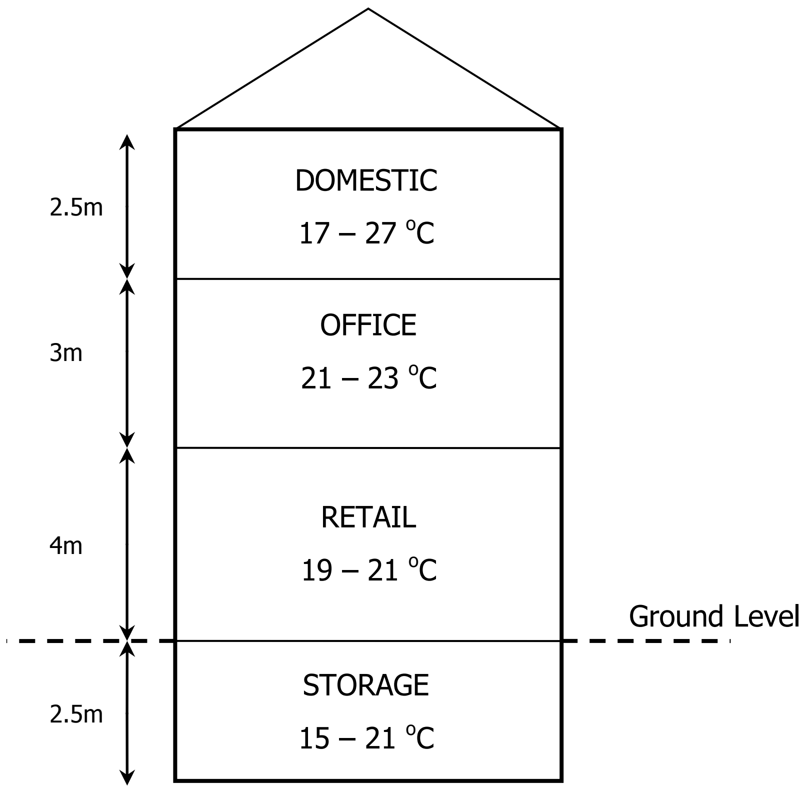


Figure 2.6: Simplified diagram of a mixed-use (composite premises) building, with design operating temperatures . *

* Temperatures taken from *CIBSE Concise Handbook* (Armstrong, 2003, page 2, Table (A) 1.1)

This simplified diagram shows that not only may the design/operating temperatures of each premises vary, but the wall areas of each may differ. The set point temperatures for each premises may be different and vary during the day/night. The percentage of glazing for each premises may also be different, affecting solar gain and heat loss. Further complications arise when party walls exist and/or adjacent premises do not have a thermally controlled environment and heat flows are likely to be increased.

Finally, the appliances used in each activity space of the premises are likely to differ, affecting internal gains. Information on these gains can be expected to be beneficial to the energy modelling of premises and buildings.

2.1.8 Energy Consumption Records for Buildings and Premises

Energy consumption bills are probably the most common form of energy consumption data, for buildings and premises. In terms of analysing and describing the energy consumption of existing buildings and premises, the bulk of research concentrates on premises, as energy consumption is most frequently measured and billed at the premises level. However, this is not always the case. For example, office tenants may have their energy consumption charged according to the floor area that is rented, with the whole building's consumption divided according to the areas let. In this example, the building's energy consumption may be discovered relatively easily, by referring to the building's energy meters, but the consumption of each of its premises would be less easily defined. In some cases HVAC services are centrally controlled and only the electricity consumption is billed per premises. Thus, estimating the energy consumption of buildings and premises, using the same procedure, becomes problematic.

Further difficulties arise when premises are spread across a number of buildings for which there may be a single billing meter. Where individual parts of multi-building premises are billed individually, the energy consumption of the premises may be gathered with relative ease, but this would not necessarily mean that the whole of each of the buildings containing the premises could be analysed.

As energy surveys are frequently commissioned for the financial benefit of those responsible for paying for the energy consumed, they tend to be based upon premises rather than buildings. This is one reason why energy consumption data and energy survey data are less easily accessed in the non-domestic sector than in the domestic sector, where each building is more likely to be under single ownership and that owner may be contacted more easily.

2.2 Describing, Recording and Categorising the Stock

Built form is a determinant of thermal performance of buildings and thus their overall energy consumption. However, without activity, a building does not consume energy. Activity tends to be the overriding determinant of energy consumption (see Section 2.2.2), but activity can also have a profound effect on internal gains and these affect the overall energy consumption of buildings, through influencing HVAC operation.

In order to understand the building stock, its characteristics and how characteristics interact, it is necessary to describe and record the stock in a structured manner. The structure needs to take into account both the physical aspects of buildings and the activities of premises. This section describes and discusses these issues.

2.2.1 Built Form and Service Systems

2.2.1.1 Effect of Activity at Construction

Buildings are generally designed and constructed with a purpose in mind, so it is likely that the physical characteristics of most buildings are at least partly determined by a desire to make the building fit for use. This original intended use, together with the building technologies, regulations and architectural fashions of the time, will usually be a key determinant of the built form and other physical characteristics of a building. A new construction can be expected to be a coherent design, with structural, fabric and service systems working together to deliver a building that is suitable for its intended activity.

2.2.1.2 Contemporary Styles and Practices

The UK non-domestic stock has a wide variety of built form styles, resulting in part from the UK's built environment being in a state of mature development. Over the time frame of centuries, there have been many styles of building, even for largely identical building activities. For example, in purpose-built warehouse space, a style of the late Victorian era can be seen in buildings with multiple storeys, windows and solid brick walls. Modern warehouse space tends to be single storey and shed-like in structure, predominantly top-lit and with minimal window areas. These two building types may have been designed to house the same overall activity, but their energy use characteristics may differ markedly.

The age profile of premises in England and Wales, as shown in Figure 2.7, below, indicates that much of the non-domestic building stock is more than 30 years old. This portion of the stock, due to the need for modifications resulting from changes of activity and changes in building practices, may have undergone some modification to aspects of its physical characteristics (BRE and RICS, 1992). Examples of modifications would be window replacement, roof replacement, or replacement of a heating system.

Some of these buildings may even have undergone a major alteration to the fabric of (some of) the building.

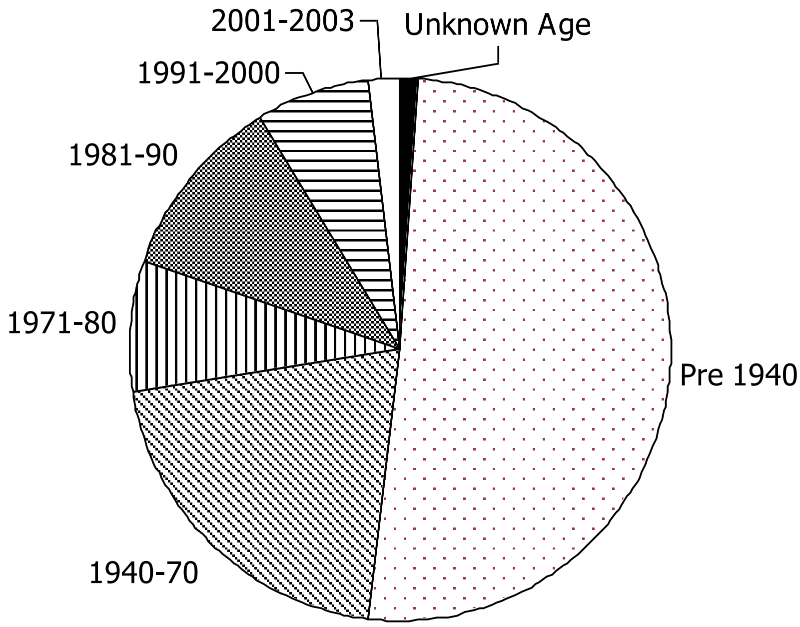


Figure 2.7: Age profile of non-domestic premises in England and Wales in 2005 (DCLG, 2005a)

The greater the time period between initial construction and the implementation of a modification, the greater the likelihood that the modification will not be completely coherent with the original building design (Mansfield, 2009). It is logical to assume that older buildings are likely to have undergone more modifications than newer ones and that each modification adds to the heterogeneity of the stock (BRE and RICS, 1992). However, there are also buildings that are so specialised that they may remain unchanged, for example public lavatories.

2.2.1.3 Energy Performance Standards

Beginning in 1985, the UK government took steps to reduce the energy consumption of new non-domestic buildings through legislation. In England and Wales, this legislation currently takes the form of the *Building Regulations, England & Wales* and its application is set out in *Approved Document Part L2 [A and B]: conservation of fuel and power* (DCLG, 2010b, DCLG, 2010a). The later versions of the regulations have also stipulated requirements applicable to major refurbishments of buildings (*Part B*).

Since inception, the Building Regulations have become increasingly stringent in their attempts to reduce energy consumption in buildings. This drive towards energy conservation has an effect upon the building systems and materials used in the construction and refurbishment of buildings, such as in thermal fabric components, glazing, thermal comfort services and domestic hot water services.

2.2.1.4 The Non-domestic Building Stock Database

The built form and other physical characteristics, such as glazing and heating and ventilation and air conditioning (HVAC) systems, of a building, can have a marked effect upon its energy consumption. To best measure the effects of these characteristics, within the stock, it is necessary to place them into a classification framework, to allow for analysis and comparison.

Steadman et al (2000a) have developed a system for classifying the built forms of the UK's non-domestic building stock. This system is used to inform the Non-domestic Building Stock (NDBS) database, in research carried out for the Department for Environment, Transport and the Regions (DETR) (Penman, 2000).

The NDBS study of built form and the physical characteristics of non-domestic buildings is based upon external surveys of buildings at 3,350 addresses, in areas of four towns in England; as a consequence, the surveys are generally known as the Four Towns surveys (Brown et al., 2000). The surveys sampled areas of Swindon, Manchester, Tamworth and Bury St Edmunds and this is currently the only large scale study of the built form of the UK's non-domestic building stock.

The system of classification, developed from analysis of the Four Towns surveys, has 14 primary forms, with three composite forms and 14 further parasitic built forms. Where the system encounters a building with a complicated built form, the overall building is separated into individual parts that conform to classes. Using this method, any part of a building should fall into one of 31 built form classes. As the classification is based predominantly upon shape, it is possible to analyse most buildings, regardless of the complexity of their overall form, or their size. Essentially, the added detail, allowed by the breaking-down of the building into individual built forms, enables a simplification of the description of the entire building, because it is possible to account for each major component of its complex overall form. In consequence, the energy consumption factors dependent upon built form, can be identified more easily.

2.2.1.5 Building Services

Rickaby and Gorgolewski (2000) developed a classification system for the HVAC systems used in non-domestic buildings. The classifications are ordered according to the scale of the system – small, intermediate, packaged, or large – with subcategories according to fuel type, distribution system and control method.

Marjanovic-Halburd et al (2008) have produced a taxonomy of energy-consuming appliances, which includes fixed systems, such as HVAC and lighting. The taxonomy also includes other appliance types, ranging from catering equipment to mobile phone chargers.

Rickaby and Gorgolewski's classification system deals with HVAC equipment, exclusively, so it falls outside the aim of this research. Marjanovic-Halburd et al's taxonomy is more relevant, but only for the appliance aspects of its classifications.

2.2.1.6 Classification by Building Regulations

Building Regulations are designed to have an effect on the energy consumption of buildings through their stipulation of standards of thermal performance of building elements, or in more recent years overall performance of the building compared to a performance standard. These standards make it possible to classify buildings based upon their age and the regulations that were in force at the time of construction (Smith, 2009), as a means of estimating their thermal performance. This method of classification is also used for the domestic stock, (Firth et al., 2009), but is potentially more precise in its categorisation, due to generations of domestic buildings having been subjected to energy performance regulations for much longer.

2.2.1.7 Other Building Classification Systems

There is a number of building component classification systems that could provide information about buildings. Such sources would include sophisticated systems of detailed data recording as: BS ISO 12006 and 4157 (International Organization for Standardization, 2006, International Organization for Standardization, 1998) and RIBA Uniclass (Construction Project Information Committee, 1997). However, these are only accessible via direct contact with the building occupier/owner and the structure of these classifications is very sophisticated, with many classes of building component. Use of these standards has only become more common quite recently, so they would exist for only a very small percentage of the total stock. Due to the problems of access and the sheer volume of data that might require processing for each building, these building information structures are impractical for use in stock modelling.

2.2.2 Activities in Premises

As indicated above, the activity performed within a building can determine its built form and certain activities may be associated with built forms, but energy consumption is predominantly determined by the activity carried out within the building. It is possible for a building to be used for an activity that does not consume any energy, for example small lock-up garages, or agricultural barns, that contain no powered service systems. As activities in premises are the most significant driver of energy consumption in buildings, a robust system of classification for activities is a prime requirement for building and premises energy consumption models. So, just as built form can be classified, it is necessary to use a classification system to allow the analysis of activities in the stock.

Unlike the domestic building stock, which has one fundamental activity – that of being a place where people dwell – the non-domestic stock has great diversity in its activities. Indeed, the domestic stock can be described using only 47 archetypes (Firth et al., 2009), whilst Pout (2000) argues that the non-domestic stock would require approximately a million categories to account for its combinations of built form and activity. As the range of activities in the non-domestic stock is so diverse, any classification system should strive to encompass this diversity without being so detailed as to be unwieldy.

2.2.3 Requirements of a Non-domestic Activity Classification System

Robinson et al (2009, page 1083) state, when describing the requirements of an energy model, *"For the purposes of urban scale simulation, it is important to achieve a good compromise between modelling accuracy, computational overheads and data availability."* The second of these three requirements is gradually becoming less of a restriction, as computing power improves with time. So, the first and third criteria are becoming increasingly important.

In Bruhns et al (2006, page 5), it is stated that a classification of the non-domestic stock needs to:

- "*be applicable to all of the non-domestic stock and convey its heterogeneity*
- *identify and separate activities that may be expected to be associated with substantial differences in energy use, and to some extent the physical nature of the buildings those activities tend to be carried out in.*
- *result in a manageable total number of categories.*
- *be able to be populated with data from existing data sources, while preserving as much as possible of the information content from that data.*
- *operate so that each type of premise found in the real world has a reasonably unambiguous place within the classification."*

These requirements largely follow those for the Non-domestic Building Stock database, stated in an earlier paper (Bruhns et al., 2000), except that, in the earlier paper, requirements also included the need to:

- *be flexible enough to allow different analytical groupings*
- *allow for grouping of premises into categories of similar energy consumption patterns*
- *avoid creating classes with very small numbers of premises*

Subsequent work on the NEED project (Neffendorf et al., 2009) (see Section 2.2.8) shows that the ability to join sources of information into a cohesive whole, in a robust fashion, is significant and challenging. This is particularly the case when trying to accommodate issues of commercial confidentiality and Intellectual Property Rights.

The following sections 2.2.4 to 2.2.8 describe existing classifications for activities in the non-domestic stock, with relevance to stock energy consumption modelling.

2.2.4 DUKES

The Digest of United Kingdom Energy Statistics (DUKES) is a valuable high level source of information about energy consumption in the UK (DECC, 2011a). The DUKES reports are more concerned with recording, monitoring and analysing the energy consumption of sectors of economic activity and are not directly applicable to urban scale building stock energy modelling. However, at the national scale, they provide a means of comparing estimates of consumption, according to economic end uses.

2.2.5 The Valuation Office Agency

The Valuation Office Agency (VOA) is tasked by the UK government with placing a value on premises for real estate taxation purposes, in England and Wales. For non-domestic premises, this form of taxation is known as Business Rates. Due to the statutory basis of the VOA's role, the data it collects is the most valuable, publically accessible, source of information on the non-domestic stock and is probably unrivalled in its extent of coverage and level of detail, compared to other data on stock across the globe (Bruhns, 2000). The VOA's survey methods and data are described in detail in Chapter 4.

2.2.6 Local Land and Property Gazetteer

The Local Land and Property Gazetteer (LLPG) is a record of addresses – premises number and street name – maintained by local authorities. The LLPG from each authority is collated into the National Land and Property Gazetteer (NLPG) as a central, standardised repository of information on the buildings, land and premises in England and Wales (NLPG, 2010).

Premises in a LLPG can be identified using the same unique identifier as is used in the VOA databases (see Table 4.3, on page 110). A key attribute of the LLPG is that it contains records for Topographical Identifiers (shortened to TOIDS), which can be used to identify the geographical location of the premises and link them through the Ordnance Survey MasterMap geographical information system, to postal addresses.

2.2.7 Non-Domestic Building Stock Database

The Non-domestic Building Stock (NDBS) database uses a sophisticated, multi-layer classification of building activity (Bruhns et al., 2000). The system gathered information from many sources but is primarily based upon the classification of premises used by the Valuation Office Agency (VOA) (described in Section 4.4.1), with additions and adjustments to take into account premises types that do not appear in the Rating List. The stock is classified using the hierarchy shown below in Figure 2.8.

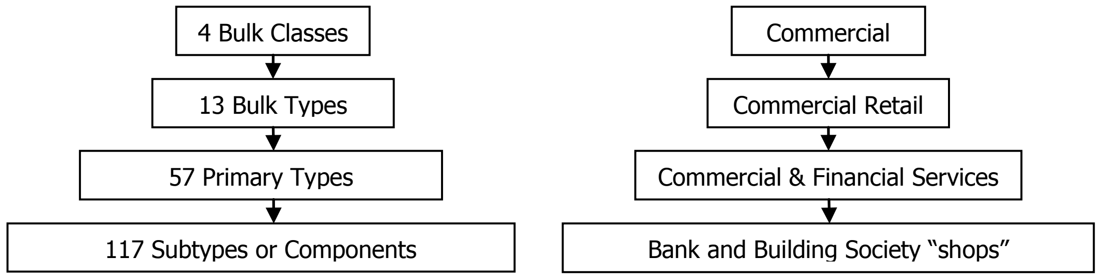


Figure 2.8: Hierarchy of activities used in the NDBS, with example of application

The work by Bruhns et al highlighted the diversity of classifications for some premises/businesses, that are used by different organisations and a good deal of effort was used to eliminate double-counting between data sources.

The classification system does not use any subdivision of premises, by area or activity, below the Subtypes and Components; for example, a "Bank shop" is not subdivided into its various areas of activity, as is generally recorded in the VOA Summary Valuation (SMV) database (see Section 4.4.2, for a description of the SMV). Bruhns et al identify that an analysis of Line Entries, which are subdivisions of space within premises, held in the SMV, could add to our understanding of the non-domestic building stock.

2.2.8 Non-domestic Energy Efficiency Data (NEED) Framework

The NEED project aims to develop a data framework for the recording of information about the non-domestic building stock (Neffendorf et al., 2009). NEED builds upon the development of the Non-domestic Building Stock database (NDBS) and the CaRB project (see Section 2.4.3), to lay the ground for a national centralised source of information on non-domestic buildings, their energy consumption and the characteristics that affect the consumption. To achieve this end, like the NDBS, the project has drawn from a number of sources and describes how these may (or may not) be linked in a robust fashion. Again, the centrality of the Valuation Office databases is highlighted.

A key departure from previous studies is the work to study the linkages between and the ability to collate data from:

- Ordnance Survey MasterMap Topography Layer (TOIDS)
- Ordnance Survey MasterMap Address Layer 2
- NLPG/LLPG listings
- VOA Rating List and Summary Valuation (SMV) databases
- Ordnance Survey Points of Interest
- Interdepartmental Business Register

The other major aspect of the NEED research has been how to link energy consumption meters, and thus actual consumption, to the collated sources, above. Although a major source of data, in the NEED structure, would be the VOA SMV database, it appears that the finest level of detail to be used would be premises type (either by Special Category or Primary Description code) and total area per premises. There is no indication that Line Entries would be used for analysis of space use in premises, though the Adjustments field might be utilised for identifying the existence of air conditioning. Adding Line Entry information may improve the level of detail and usefulness of the NEED structure.

2.3 Single Building Energy Consumption Models

Energy consumption models, for single buildings or premises can be roughly split into two types: those used for designing a building and those used to meet requirements for compliance with regulations, or to voluntarily assess the performance of buildings and premises during operation. The models used at the design stage, require levels of detailed data that are not accessible for the building stock, as a whole. These detailed data would include dimensional measurements, information on building fabrics and services. The models used for compliance purposes are mostly much simpler and take the form of some type of energy or emissions benchmarking system. Exceptions to this are the Simplified Building Emissions Model, which is the approved version of the National Calculation Methodology (DCLG, 2008b) and other sophisticated software that has been approved for use as a compliance tool.

Energy Performance Certificates (EPCs) are used to measure the theoretical performance capabilities of a building, or premises. Display Energy Certificates are an operational benchmark and are generally applied to premises. Both of these are requirements of the European Union Energy Performance of Buildings Directive (EPBD) (Council of the European Union, 2010). EPCs could, if government decides to release them, be a valuable source of data on the physical characteristics of the non-domestic stock. A limited amount of information can be gleaned from a central database of DECs – such as floor area, premises type, annual energy consumption and suchlike – but the numbers of premises are still very low, due to their only being required for public buildings, with public access.

In addition to these benchmarks required by statute, there are several others, such as those provided by the Chartered Institute of Building Services Engineers (CIBSE) (Field, 2006, Field, 2008).

2.4 UK Multi-building and Multi-premises Energy Consumption Models

This section describes the models currently available for modelling the energy consumption of multiple buildings. The models are listed chronologically, with the earliest developments first.

2.4.1 NDEEM

The Non-domestic Energy and Emissions Model (N-DEEM), developed by Pout (2000), is a model to estimate the current end use energy consumption of premises in the UK non-domestic stock. N-DEEM is also aimed at predicting the potential cost-effectiveness of energy consumption technological interventions, together with projections of future energy consumption patterns and the potential for carbon savings. The model uses the national floor areas, primarily classified by building occupier activity, provided in Bruhns et al (2000), extrapolated to cover the whole of the UK. The eleven groups of building activities are given as:

Commercial offices	Communication and transport
Education	Government
Health	Hotels and catering
Other	Retail
Sports and entertainment	Unclassified
Warehouses	

For each of the above classes, the following energy end uses are estimated:

Heating	Hot water	Catering
Lighting	Cooling and ventilation	Computing
Other	Process	Unknown

The consumption breakdown, for fuel types, is given for electricity, gas, oil and solid fuel.

The energy consumption inputs for the model, in the form of energy intensity (GJ/m^2/year) for each premises activity, are sourced from the SHU energy surveys, plus some other sources. Where there are insufficient survey data to provide a value for energy intensity and a fuel use pattern for a given premises activity, data are substituted by using an activity with similar energy consumption characteristics.

N-DEEM produces predictions of annual consumption profiles for premises, not buildings. For consumption prediction purposes, N-DEEM is also only designed for use on the national building stock, not any smaller area, or smaller number of buildings, such as at the city scale.

2.4.2 EEP

The Energy and Environmental Prediction (EEP) model, developed by Jones et al (2000), has been designed to be modular in form and for use by local authorities to help inform and plan local development. The modules for the model are used to predict the energy consumption of, and CO_2 emissions from, the domestic sector, industrial processes, the commercial and public (non-domestic) sector and road traffic. The model can be used in its entirety, or each component can be operated independently. The model is able to function at an area resolution of seven-character post codes, that is, approximately 15 addresses (Royal Mail, 2003).

For the non-domestic sub-model, the EEP model requires individual external surveys of buildings, to identify some of their key physical characteristics, such as age and number of storeys. The floor areas of buildings are calculated from data accessible via the geographical information system (GIS) program MapInfo. The principal activity of the "property" (page 864) is gathered from "local council rates database and site visits." (page 864). This database is probably the Rating List (see Section 2.2.5) and thus does not contain floor areas of premises. It is not clear how properties – presumably premises – are related to the buildings being assessed.

The energy consumption of the properties – both fossil fuel-based and electricity – is derived from benchmark data. These benchmarks were developed by the Energy Efficiency Office (EEO), in the 1990s. The categories are defined by activity and are thus premises-based rather than building-based. It should be noticed here that there is a shift, in the EEP model, from the physical characteristics of the building to the operational consumption patterns of its activity.

The non-domestic benchmarks, used in the EEP model, have 13 activity groups and 48 sub-groups, each with three bands of energy performance, to cover the diversity of activities, built forms and consumption patterns of the non-domestic stock in the area to be assessed. This may be compared to the 100 categories used to estimate the energy consumption of the more homogenous stock, in the EEP domestic sub-model. The energy performance band is a matter of judgement by the model user, "…usually based on the age of the property unless other information has been obtained." (page 864).

The EEO benchmarks are based upon the activity carried out in premises, and the EEP model does not make it clear how the age of the building, or the other information, affect the energy performance of the activity. The age of the building is more likely to have an effect upon the thermal performance of the building fabric and its HVAC systems (BRE and RICS, 1992, Smith, 2009), but how the efficiency of energy used for activities can be gauged from outside a building is not explained by Jones et al.

Overall, due to the requirement to visit individual non-domestic buildings, the EEP model is more suited to the estimation of the energy consumption of relatively small numbers of buildings, rather than at the urban scale as sought in this research described in this thesis.

2.4.3 CaRB Stock Model

The Carbon Reduction in Buildings (CaRB) project produced a stock energy model for England and Wales, with further applicability to the whole of the UK. The model, as described in Bruhns et al (2006), may be used to estimate the end use energy consumption of the non-domestic building stock, using primarily VOA data sources

(Rating List and SMV) to allocate premises to a division of the NDBS activity classification system.

Bruhns et al point out that the floor areas for approximately 20% of premises (by number) are not recorded in VOA data sources for the year 2004, or any other available sources. However, floor areas for most premises types can be imputed from the premises' rateable value (RV), in the Rating List, because there are records of RV (together with floor areas) for at least a number of each premises type within the VOA SMV data.

Mean energy intensity values (kWh/m^2/year) are derived from the SHU survey data, with the SHU premises being allocated to an appropriate activity class. The mean energy intensity of each activity class is then applied to the corresponding sum floor area, to produce estimates of the annual energy consumption of end uses, for each activity class. The CaRB stock model underestimates energy consumption by 15 % for the public, commercial and miscellaneous premises sectors, compared against the UK data from the Digest of United Kingdom Energy Statistics (DUKES). This is a reasonable degree of accuracy, considering that the DUKES figures are for the UK and the CaRB output is for England and Wales. For the industrial sector, the model underestimates by approximately 48%, but this is attributed to the DUKES figures including process energy, whilst the CaRB model does not.

The CaRB non-domestic stock model has low resolution in terms of it being a model for the stock of England and Wales, but it is a bottom-up model, constructed from data on individual premises. The energy consumption of heating, cooling, lighting, computer equipment, domestic hot water, catering and "other" end uses can be estimated for each premises type in the NDBS premises activity classification. By using the NDBS classification hierarchy, it is possible for the model to generate outputs at varying levels of activity detail, but the greatest level of detail is for the total area of a single premises class.

2.4.4 The Non-domestic Carbon Scenario Model (NDCSM)

The model developed by Hinnells et al (2008) has been designed to estimate the energy consumption, and consequent CO_2 emissions, of the non-domestic stock, according to various intervention scenarios. The overall aim is to show how these scenarios might fit with meeting the aims of the policies laid down in the Climate Change Act (see Section 1.1).

The NDCSM, as published, is not yet applicable to all non-domestic activity types, as it is currently limited to:

Boarding/guesthouse	Hotel or motel	Public house
Restaurant	Takeaway	Commercial warehouses
Commercial offices	Central government offices	
Local government office	Dry cleaner	Laundrette
Hairdressing/beauty salon	Post Office	Bank or building society
Commercial services	Supermarket	Large shop
Market stall	Small or general shop	

Other classes, such as factories (a significant portion of the UK stock), are omitted.

The historical floor area inputs are derived from VOA data for the total area of each premises type in England and Wales. For its most recent floor area inputs, the model uses the 2004 VOA-derived values from the CaRB non-domestic stock model (Bruhns et al., 2006). The initial NDCSM output is for England and Wales, with extrapolation, based upon population numbers per region, used to account for the stock in Northern Ireland and Scotland.

The non-domestic energy reference data for the NDCSM are sourced from the SHU surveys, as this is the only large-scale study of energy consumption in non-domestic buildings that is based on detailed surveys. However, Hinnells et al criticise the SHU data for being biased towards smaller premises (the paper uses the term "buildings", but this is incorrect) and for not being representative of the UK stock (page 7). To some extent, this is valid criticism, but the SHU data are the only data accessible for the purpose. There is also criticism of the aggregation of energy consuming equipment under headings of end use such as "heating" and "lighting", because this does not allow detailed analysis of the equipment. The full SHU database does contain detailed descriptions of every piece of equipment, including coding systems for use profiling, equipment type, power rating and so forth. The SHU surveys and their resultant datasets are described and discussed in detail in Chapter 3 of this thesis.

Being aware of the age of the SHU data, the NDCSM methodology has returned to the base SHU datasets to make allowances for the increased prevalence of computing and associated equipment, as well as the increased efficiency of modern lighting equipment.

As published, the model outputs for each of three energy policy scenarios can be displayed for the national end use energy consumption of the office, retail, warehousing, catering and hotel activity sectors. As the model uses activity and floor area data inputs from the VOA – via the CaRB stock model – at the national scale, the model is not applicable to smaller portions of the stock, such as a region, city and so forth. Also, the model uses data for classes of premises activity, not individual premises or their Line Entry subdivisions.

2.5 Summary of Chapter 2

This chapter has defined what constitutes "non-domestic" for this research and explained the differences between buildings and premises, and why the terms should not be used interchangeably. Models for estimating energy consumption in the stock should be identified according to whether they are intended for premises, buildings, or both. The classification of the stock may be derived from buildings or premises, but premises-based classification systems are primarily founded upon activities, not built form.

Buildings and premises change over time and a model can be used to describe this, as well as provide a structure for issues governing access to sources of information about buildings and premises. An ageing building stock is more likely to have activities performed in buildings that were not constructed for that purpose. This places an emphasis on the assertion that buildings are a unit of construction, whilst premises are a unit of operation.

Activities in premises and buildings are the prime driver of energy consumption because the activity determines the use of energy used for both the actual activity and the maintenance of an environment conducive to the performance of that activity. The energy consumed, directly by the activity, degrades to form internal heat gains, which in turn affect the consumption of energy used to maintain the indoor environment in the area of activity.

Building, or premises, energy consumption models are dependent upon access to suitable data. For the building stock, some data are accessible, but where these are for large numbers of premises, they do not carry enough detail to allow them to be used for sophisticated single building models; hence the need for specific stock models, operating at various levels of resolution. Current non-domestic stock energy models do not analyse the use of floorspace, or calculate energy consumption, at a resolution finer than individual premises.

Sources of information suitable for use in stock energy modelling can be found in the data collected by the Sheffield Hallam University building energy surveys and real estate (premises) taxation data collected by the Valuation Office Agency. The use of these two sources of information is dealt with in Chapters 3 and 4, respectively.

Chapter 3: The Sheffield Hallam University Data

The detailed energy surveys, carried out by the Resources Research Unit of Sheffield Hallam University (SHU) have formed the foundations of a significant proportion of what is known about the energy consumption characteristics of non-domestic premises and buildings in the UK. The surveys have contributed to Energy Consumption Guide 19: energy use in offices (Action Energy, 2000), the Energy Assessment and Reporting Method TM22 (Field, 2006), the Non-domestic Energy Fact File (Pout et al., 1998), the Non-domestic Energy and Emissions Model (Pout, 2000) and Energy Benchmarks TM46 (Field, 2008), for example. To date, the SHU surveys are the only known large-scale accessible source of detailed information on how energy is consumed in non-domestic premises, in the UK.

This chapter describes these SHU surveys and the resulting database of information that is the principal source of energy consumption data, used in this thesis. The methods used to process the SHU data, to obtain values (kWh/m^2/year) for internal gains resulting from appliance use, together with profiles of appliance use, in various space uses are also described.

3.1 The SHU Surveys

Between 1991 and 2000, the Resources Research Unit of Sheffield Hallam University (SHU) carried out detailed internal energy surveys of more than 700 non-domestic premises, on behalf of the Global Atmosphere Division of the Department of the Environment, Transport and the Regions (DETR), to inform DETR where energy was used in the UK non-domestic stock (Mortimer et al., 2000). Sixty percent of these surveys were carried out in 1993/1994 and were initially based on a subset of the previous Four Towns surveys by the Open University (OU) – external surveys of 3350 addresses (Brown et al., 2000). Later, the SHU surveys moved outside of the constraints of the Four Towns, so that more buildings of particular activity types could be included, due to some types not being present (or accessible) within the original OU sample.

Detailed descriptions of the survey procedures, data handling and analysis techniques, carried out for the original SHU research can be found in Mortimer et al (1999, Mortimer et al., 2000a, Mortimer et al., 2000b), Penman (2000) and Elsayed et al (2002).

Table 3.1, below, provides a summary of the SHU data that are most pertinent to this thesis.

Table 3.1: Description of principal SHU data used.

Table Description	Table Name	Field Name	Field Description	Metric	Notes
Premises basic description	Pbasdes	SHUNO	SHU Unique Identifier for each premises occupier	Code	Used for linking premises records in data tables
		OccArea	Occupied Area	m^2 GEA	Total area calculated from OU polygon areas unless floor plans were obtained
		DescActiv	Description of activity	Text	Brief description of the main activity within the building (e.g. office work, retail, etc.)
		PDcode	Primary Description code	Code	VSO Primary Description Code for occupier
Premises room details	Proomdet	SHUNO	SHU Unique Identifier for each premises occupier	Code	Used for linking premises records in data tables
		RoomNo	Room number	Numeric	Room identification number. Links to table "Pequip"
		RoomCode	Room code	Code	Code for a standard room name (e.g. "oc" = "office cellular")
		RmUseCode	Room Use code	Code	Code describing what the room is used for: usually reported by the occupant, but was sometimes decided by the surveyor
		RmArea	Room area	m^2 GIA	Measured area of room. Measured on building plan drawings, or by physical measurement of the room
		RmComment	Room comment	Text	Additional information about the room
Premises equipment	Pequip	SHUNO	SHU Unique Identifier for each premises occupier	Code	Used for linking premises records in data tables
		RoomNo	Room identification code	Numeric	Links to table "Proomdet"
		Roomname	Room name	Text	Room name (e.g. "kitchen", "office 1", etc). Provides a comparator for Proomdet.RmUseCode
		Noofitems	Number of items	Numeric	Number of items of equipment
		Itemcode	Item code	Code	All equipment is coded, with details of its description kept in a lookup table.
		Comment	Comment on the item of equipment	Text	Brief comment about the equipment (if necessary) (make & model, nameplate, power ratings, etc)
		Description	Description of item of equipment	Text	A description of the equipment, derived from the field "Itemcode". (e.g. pc, tungsten light 60W, etc.)
		Analcat	Analysis category	Text	Category of end use of the equipment, e.g. "lighting", "small power" etc.
		Usedforcode	Used For code	Text	The activity for which equipment is used; e.g. "education", "laundry" etc.
		Calckwhr/yr	Calculated energy consumption (kWh) per year	Num	The calculated annual energy consumption for this equipment in kWh (kWh/yr), resulting from equation [1]

The following points give an indication of the scale of the SHU surveys and the wealth of data they gathered:

- Premises activity: 56 types (Valuation Office Primary Description Codes)
- Each premises' total occupied area (m^2)
- Activity in each room: 63 classifications across 11,919 rooms
- Area (m^2) of each room
- Energy-consuming equipment in each room: 372 descriptions/codes (63,000 records and 248,000 pieces of equipment)
- Reported usage patterns of equipment
- Each premises' hours of occupancy
- Metered energy consumption for at least one year, taken from billing records

Two crucial aspects of the SHU research were the collection of information about all the energy consuming equipment in the premises and the gathering of measured energy consumption data. The energy consumption of each piece of equipment was calculated using equation [1], below.

W * L * O * U = energy consumption per item of equipment per year as kWh/yr [1]

Where:	W = Power of equipment item (Watts)	(recorded/inferred data)
	L = Load factor for item	(inferred data)
	O = Premises occupation hours/year	(reported data)
	U = Utilisation factor for item*	(reported/inferred data)

To calculate the total energy consumption of each premises, the output of all instances of [1] was summed. This calculated value was then compared to the billed energy consumption of the relevant premises, as a means of validating the calculated consumption. It was not uncommon for this method to return a total calculated consumption within 20 – 30% of the metered energy records (Mortimer, 2009).

The power ratings of equipment were mostly recorded values, but the utilisation of the equipment was reported, usually by the premises' occupants, or occasionally inferred

* The utilisation factor of a refrigerator, for example, was given as 0.33 to account for its compressor operating only when required to cool the refrigerator, though the appliance would be switched on all the time.

by the surveyors. Recorded data, such as energy meter readings are less open to interpretation than are reported data, such as hours of occupancy or utilisation. Where discrepancies between the calculated total consumption of the premises and the metered consumption were found, the surveyor would generally adjust the utilisation factor, as this was not a recorded figure and thus most open to latitude in interpretation. This method of adjustment maintained the integrity of the recorded data.

Where the difference between calculated and recorded consumption could not be reconciled, a "balancing figure" would be applied to a notional "Room 0" to equalise the values and record the difference. Room 0 would have no floor area, the activity would be logged as "not applicable" and the balancing figure value could be either positive or negative.

3.2 Overview of the Methodology Applied to the SHU Datasets

The methodology of this thesis is applied to the SHU datasets in several stages. At the start, there are the raw SHU data and at the end of the process, there is information that can be used as an input for non-domestic stock models. The overall methodology, for the preparation and analysis of the SHU data is shown below, in Figure 3.1. The methods applied to the data, at the various stages shown in the flowchart, are explained in greater detail, in later parts of this chapter. In the figure, the novel outputs gleaned from the data, for stock modelling, are shown in the shaded parallelograms, to the right.

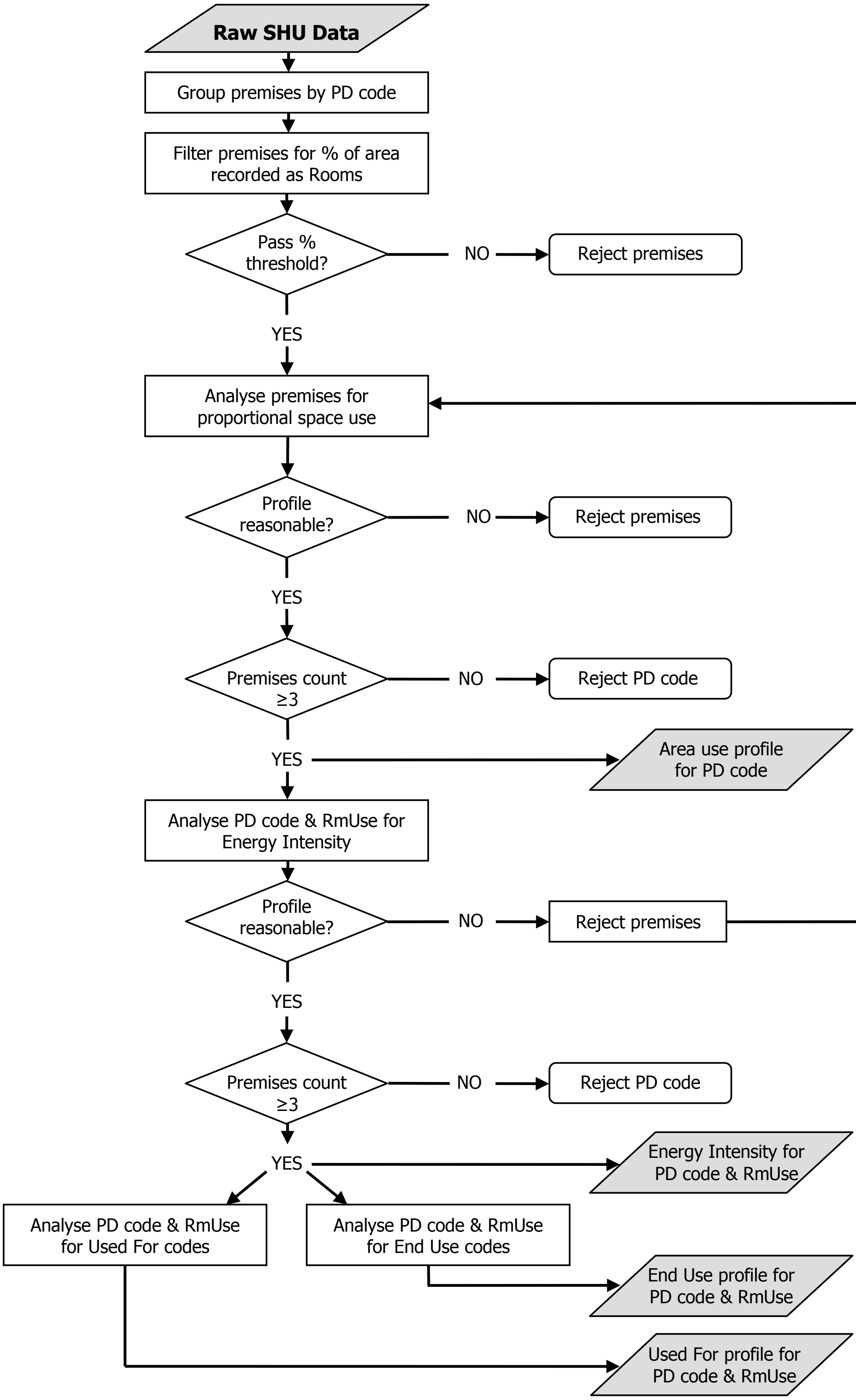


Figure 3.1: Flowchart of the overall methodology applied to the SHU dataset.

3.3 Cleaning the SHU Data

As this research was able to make use of the raw data collected by the SHU surveys, as recorded in the relevant database tables, each premises' dataset was assessed for completeness and apparent errors. To remove basic errors, inspections and corrections were carried out to eliminate non-numerical records from numerical fields and correct various typos in text and code fields. A few double entries of rooms were also removed.

The justification for the data cleaning methods were taken from Chapman's (1991) study of the accuracy of building surveys. Even when there are prescribed procedures for the collection of data, there is evidence that variability in data still occurs. Such variability, which is manifested as inaccuracy in the data, was quantified for energy surveyors undergoing training to become National Home Energy Rating (NHER) energy assessors. In the study, it was demonstrated that even where surveyors undergo the same training, the data they input to the NHER computer model can vary the results by as much as 10%.

Chapman describes the potential errors made by the trainee NHER surveyors as being of five types:

1. Observational errors. A building's feature is unnoticed. These are more common in surveys of actual buildings than in surveys based on architectural drawings.
2. Conceptual/Mapping errors. A building feature is noticed, but there is a mismatch in what is observed and how the data is put into the model.
3. Convention errors. These may be errors in how to measure features. There will also be instances where deciding upon a category, to which a feature should be allocated, is not clear.
4. Measurement errors. These arise from the use of the wrong scale on a ruler, when measuring from drawings, for instance. Chapman notes that architectural drawings are frequently accurate to within 3%.
5. Keyboard errors. These are simple errors arising from the inputting of data into the NHER software.

Each of these five types of error could appear within any given building survey and Chapman points out that attributing a particular error to an error type can be problematic. It might also be expected that where a multi-building energy model is based upon a number of sources of empirical data, collected through the use of surveys, the identification and quantification of errors would become increasingly difficult. It is also noted that the surveys analysed in Chapman's work were examined, so it might be assumed that the surveyors' work is likely to have been undertaken with greater rigour than would be the case in normal circumstances, though conversely, familiarity might reduce mistakes.

Convention errors are less likely to occur as a surveyor becomes more familiar with a particular survey process/tool. However, unidentified by Chapman, it might also be the case that any erroneous allocation of characteristics to classifications could become ingrained, over time. The significance of a repeated misclassification would depend upon the importance of the characteristic. Chapman points out that the misclassification of boiler type, within the NHER program, can have a profound effect upon the final results, although this might also be attributable to an observational error.

With regard to measurement errors, the paper dates from 1991, so it might be assumed that Chapman is describing non-CAD drawings. However, Chapman also indicates that the dimensions of drawings, even when measured accurately, sometimes do not match the actual dimensions of the building they represent. The potential for architectural drawings to be wrong by 3% might not be a result of non-computer-based drawings, but due to dimensional tolerances in the actual building; thus it is the building that has not been constructed according to the drawings, rather than the drawings being wrong. Such a degree of inaccuracy makes the calculation of energy consumption across many buildings, should this be based on detailed dimensional data, even more problematic for non-domestic buildings, due to their frequently complex shapes. If the measurements are obtained through surveys of the actual buildings, it seems that they would be commensurately less accurate. One caveat would be that Chapman's study was based upon surveys of domestic buildings and it is not known whether dimensional tolerances are affected by building size and/or by whether they are domestic or non-domestic buildings.

With the existing prevalence of computer-based data storage, it can be assumed that keyboard errors are inherent within surveys. Chapman indicates that one error per hundred keystrokes can be expected, though this should be reduced for skilled keyboard operators and touch typists. Chapman also points out that the effect of a single mistyped data input will depend upon the importance of the field into which it has been typed. For example, the inputting of an error of 30cm in the height of a storey could have a profound effect upon the calculated energy consumption of a twenty storey building, but less so of a single storey structure. Clearly, the more data that are required to be inputted, the more errors there are likely to be.

3.3.1 Assessing the Completeness of the Premises Datasets

The process for profiling space use in premises required that the use of space could be established with a reasonable degree of confidence. To identify which premises should be included in the space use analyses, the premises from each Primary Description (PD) class were grouped together, as the PD code would be the initial means of categorisation of activity. Where a PD code grouping contained only one or two premises, the PD code played no further part in the research, as it was deemed to have too few datasets to provide meaningful results. This process reduced the number of premises in the sample from 738 to 711.

In the early stages of the SHU project, not all premises had areas recorded for their constituent rooms, as initially this was not a requirement of the surveys. In this research, if large areas of premises could not have their activity identified, it would be unreliable to include these premises in the analysis of space use. A threshold for the "completeness" of the premises' room records was established to maintain the representativeness of the sample.

Initially, an acceptable threshold for completeness of room records was established by including only premises where the sum of the room areas (field name RmArea), of each premises was equal to or greater than 90% of that premises' occupied area (field name OccArea). This reduced the total sample size from 738 to just 146 premises and was deemed unacceptable. A more reasonable and usable threshold for completeness was established by including only premises where the sum of room areas, expressed as a percentage of the occupied area, was equal to or greater than one standard deviation below the mean for a given Primary Description. These initial filtering processes give a working sample size of 338 premises, as shown in Table 3.2, below.

Sample sizes of less than three were deemed to be excessively unreliable and were excluded. After each subsequent analysis and filtering process, the number of premises was checked to ensure that there were still more than two premises in each sample.

Table 3.2: Sample sizes of premises types at start of space use filtering/analysis process.

PD Code	Primary Description	Count of premises carried forward to analyses	Lowest percentage of completeness of premises
CG	Petrol Filling Station	11	91
CH	Hotel	8	73
CL	Public House	5	79
CO	Office	80	78
COM	Shared space	0	-
CR	Restaurant	4	84
CR1	Cafe	3	74
CS	Shop	131	73
CS1	Bank	17	82
CS5	Launderette	3	74
CS6	Post Office	7	75
CS7	Showroom	3	90
CW	Warehouse	5	90
CW2	Storage Depot	4	90
EL	School	31	80
IF	Factory	5	89
IF3	Workshop	9	81
LC1	Clubhouse	6	84
ML	Offices (Local Govmt)	6	85
VAC	Vacant areas	0	-
		TOTAL 338	**MEAN 82**

As Shared Space (PD Code "COM") and Vacant Areas ("VAC") do not appear in Valuation Office Agency data, these were excluded from analyses. For the space use analysis, the Local Government Offices ("ML" PD Code) were merged with the Office ("CO" PD Code) category, to further improve the latter's sample size. This amalgamation is justified by only 1.65% (7747m^2) of the summed areas of the ML and CO PD Codes (470,795m^2), being classed as ML in the test urban area (Leicester City Council) VOA datasets.

The filtering process, described above, indicates how the sample sizes change, as the requirement for detail and accuracy in each dataset increases. This effect continues throughout the filtering and data analysis processes. None of the premises has a percentage of completeness lower than 73.

No correlation was found between Occupied Area and percentage of completeness, or the number of rooms in premises and percentage of completeness. The r^2 values are 0.0021 and 0.0083, respectively, implying that the accuracy of recording rooms and their areas in the surveys was not dependent upon the size or complexity of space use in premises.

A new database table was created, named PremsFilter, which recorded whether premises had passed the initial filtering processes.

3.4 Profiling Space Use in the SHU Samples

Premises that passed the initial filtering process, were retained in their Primary Description classifications and analysed for patterns of space use. This process also involved a degree of data filtering, as potentially-suspect values were revealed. To speed the process, the original Proomdet table, which held the data most relevant to Room Use profiling, was copied and rationalised to give a smaller, but focussed, dataset for each premises. This new table was named MasterRooms.

To identify the patterns of Room Use, within each Primary Description category, the area of each room was expressed as a percentage of that premises' sum of recorded room areas. To identify potential anomalies, the highest percentage value of each room type was highlighted and the base datasets were examined to establish if the value was exceptional. Some of these values were found to be caused in records where the areas were not recorded in several rooms but were apparently amalgamated and allocated to only one room. As this situation obscured the true areas of individual rooms and sometimes included disparate Room Uses within one area record, it was necessary to remove these premises from the usable data, so the PremsFilter table was updated to record this.

A second flagging system was applied to the data, to indicate where percentages of total Room Use area were noticeably higher than the mean for that Room Use in that premises type. The flag activation was set at percentages ≥5 standard deviations above the mean. The threshold of five standard deviations was chosen, over the usual three, because at three standard deviations, a great number of premises exhibited apparently exceptional uses of space. However, upon inspection, many of the Room Uses flagged at 3 standard deviations proved to be entirely feasible. Five standard deviations below the mean would usually generate a negative figure, which would be irrelevant as space use cannot be negative, so minimum values were not identified during this flagging process. However, the issue of exceptional minimums is dealt with in Section 3.5, below. The existence of 0% use of space for a given Room Use was not exceptional, as not all, or the same, Room Uses appear in all premises of a given Primary Description category.

Cross-referencing the Room Use with information held in the Room Comment field, Room Code field, in table MasterRooms, or with information held in the Pequip table, generally enabled the flagged room to be explained. In some cases the Room Use had been misclassified and such errors could be corrected. Reclassification was based on a number of criteria including the Room Code, Room Comment, the room's equipment and pattern of its usage and, occasionally the description of the physical form of the room (held in field Rmphyscode, originally part of table Proomdet). For example, where a "store" room contained cooking equipment with long usage hours, the room would be reclassified to "cooking".

Also, where possible, rooms classified as "special use" were examined and could be justifiably allocated to one of the other existing Room Use classes. This was done because, within the VOA datasets, there is no equivalent to the "special use" category. Sometimes, reallocation was not possible and the room remained classified as "special use", but represented a reduced fraction of the sample's total floor area. Also, where there were a very few rooms of a particular type, for example the "audio" class within the Office premises data, these were allocated to a Room Use that could be judged to adequately match the appliance and use profile of the room; for example, reclassifying a teleconferencing room to the "Meeting" room class.

Once all corrections and rationalisations of Room Uses for a classification of premises had been completed, the remaining premises were once again subjected to the maximum value and 5 standard deviation flagging processes. On the second run through the processes, the data could usually be seen to be unremarkable. The cleaned data were stored in a new database table named MasterRoomsAreaProf, which also recorded which, and how, rooms had undergone reclassification.

In some cases, reclassification of rooms resulted in premises having their Primary Description classifications altered, too. Although a significant number of premises failed to meet the required standard of data completeness, some of the smaller samples were improved as a result of these reallocations of PD code. A summary of the premises that completed the area use profiling process is shown in Table 3.3, below.

Table 3.3: Sample sizes, total floor areas and number of rooms, in Primary Description classes, at completion of space use filtering/analysis process.

PD Code	Primary Description	Count of premises after space use analysis	Total area of PD sample (m^2)	Count of rooms
CG	Petrol Filling Station	11	5151	134
CG1	Vehicle Repair Workshop	3	2564	46
CH	Hotel	9	27098	653
CL	Public House	5	2183	78
CO	Office	75	89569	2327
CR	Restaurant	4	1218	72
CR1	Cafe	3	389	29
CS	Shop	126	63037	1590
CS1	Bank	16	8265	427
CS5	Launderette	3	391	31
CS6	Post Office	7	4113	131
CS7	Showroom	3	2663	50
CW	Warehouse	10	14306	156
EL	School	31	82809	2377
IF	Factory	5	12643	132
IF3	Workshop	7	1751	83
LC1	Clubhouse	6	8707	316
-	**Total**	**324**	**326859**	**8632**

Table 3.3 also shows the total area of each Primary Description sample and the number of rooms into which it is divided. It can be seen that the total premises sample has fallen from 338 to 324, a reduction of just over 4%.

A key value of the flagging process was that it removed premises deemed potentially unreliable, in terms of the records of their Room Uses, and reallocated some rooms to their proper uses. Premises with unfeasible room areas were also removed. Neither of these issues had been a problem in previous published research, which dealt with the premises in their entirety, not individual rooms.

3.5 Profiling Energy Intensity in Space Uses

To ensure a like-for-like analysis of room space use and Energy Intensity in room spaces, only premises that were included in the final output from the space use analyses were brought forward into the analysis of energy consumption.

Again, premises were grouped by Primary Description and the energy intensity (kWh/m^2/yr) of their appliance use was calculated for each room. Appliances did not include equipment that had been designated, in the original SHU surveys, as having the end uses of "heating" or "cooling". Also, only electrical energy consumption was calculated and included in the energy intensity values, so values for gas-powered catering or process equipment, for example, are not included in the calculations.

The rationale behind the exclusion of the heating and cooling end uses is that cooling and (especially) heating plant tends to be centralised and quantification of the share of its total consumption attributable to a single room cannot be known without knowing the exact thermal properties of the room and exactly how the heating/cooling is used.

Usage of gas is difficult to quantify for an individual piece of equipment, unless that single piece of equipment is the only item connected to the meter. Equipment such as gas ovens, for example, will have consumption dependent upon the temperature and duration required for cooking, so the food being cooked may govern the consumption and this cannot be known from the SHU survey data, reliably. More importantly, if equipment other than heating and cooling equipment is not sub-metered, and premises have only one gas meter, separating consumption used for equipment, from consumption used for thermal control of spaces, becomes problematic.

Returning to Brand's model of Layers of Change (see Section 2.1.2), the consumption of appliances – the "Stuff" in Brand's model – is being linked, in this research, to the Space Use layer, but made distinct from the Services, Shell, Structure and Site layers. The consumption of appliances (and thereby internal gains) is being linked to the space use, so that the building fabric, services and so forth can be dealt with separately, using appropriate modelling methods, but also utilising the internal gains profiles to inform the overall model of energy consumption.

As with the process of profiling space use, it was also necessary to ensure the robustness, and as far as reasonable the consistency, of the data used in calculating the electricity consumption of appliances per Room Use.

The calculated electricity consumption of each piece, or group of, equipment was summed for each room and divided by the room's floor area, to give a value of appliance energy intensity in $kWh/m^2/yr$. In some cases either the room area, or records of equipment, were found to be missing and these rooms were excluded from subsequent analyses, as an Energy Intensity value could not be calculated.

Grouped by Primary Description code, the values per Room Use, were examined for their highest value. The room with the highest Energy Intensity was examined for information that could explain the level of consumption. If, through the use of engineering judgement, no apparent errors were found the room was accepted, as were the datasets for that Room Use type.

The Primary Description-grouped data were then subjected to a 5 standard deviation flagging system, for each Room Use, to identify outlying values of energy intensity. Where flags were found, the floor area of the room was checked for validity, as this was most-frequently found to be too small for the reported equipment; for example, a $5m^2$ office room with 24 four-foot fluorescent tubes to illuminate it. This example also indicates how it was also possible that the floor area of the room might be accurate, but the equipment – usually the quantity of a specific item in a record – might be incorrect. As it was not generally possible to ascertain which of these two situations constituted the error, or know how to correct the error, the room was removed from the analysis. This part of the filtering process should also be seen in the context of the identification of excessively small room areas that could not be identified in the Room Use profiling procedures described in Section 3.4.

Exceptionally high values for Energy Intensity were also sometimes identified as misallocation of Room Uses, when compared to the equipment within the room and other enlightening information. Where this occurred, the Room Use was altered in line with the appliances and other information about the room, held in various data tables.

In some premises no energy consumption was allocated to some rooms, so these rooms could not have their Energy Intensity calculated. This was also the case where room areas were missing and in both cases the rooms in question could form no part of the analysis of Energy Intensity in rooms and were recorded as invalid rooms for Energy Intensity analysis. Where this occurred, the exclusion of the room was also updated in the analysis of the relevant Primary Description class.

Occasionally, rooms had no calculated energy consumption for some of the appliances in the room. On the whole, these errors were ignored, except in cases where all lighting appliances in the room had no electricity consumption, as the likelihood of lighting not being used at all is small. Where lighting appeared to be completely unused, either the room, or the entire premises were removed from further analyses. Premises removal was pronounced in office premises, where nine premises were excluded due to zero lighting energy use in many of the rooms, despite the appliances being recorded. In other rooms, there were instances of some lighting having values for consumption, but other lighting not having any. Where this was found, the room was deemed valid, as it is not always necessary to have all lighting in operation.

Unlike the process of cleaning and filtering data for the Room Use profiling, described in Section 3.4, the exclusion of individual rooms from premises was not deemed reason enough to exclude the whole premises from the Energy Intensity profile. It was considered that the effect on the Energy Intensity values of losing a few rooms was outweighed by the need to preserve overall Primary Description class sample sizes.

After rooms and premises had been checked for probable errors and the Primary Description grouping had been updated to reflect changes of Room Use and exclusions, the data were subjected to the maximum value and five standard deviation flagging procedures, for a second time. This second run through the processes indicated any remaining problem rooms and these were dealt with as described above. As was found in the space use profiling process (Section 3.4), there were still a number of rooms with energy intensities that were in excess of five standard deviations above the mean but, after investigation of the room's dataset, were found to be potentially feasible, in spite of being such extreme outliers.

Upon completion of the filtering processes, the relevant database tables were updated to reflect the excluded premises, excluded rooms and revised Room Uses. Table 3.4, below, gives a summary of the premises samples at the end of the energy intensity filtering and analysis processes. It may be seen that the sample sizes, in some cases have shrunk: the most affected sample being office premises.

Table 3.4: Sample sizes, total floor areas and number of rooms, in Primary Description classes, at completion of Energy Intensity filtering/analysis process.

PD Code	Primary Description	Count of premises after EI analysis	Total Area of PD sample (m^2)	Count of rooms
CG	Petrol Filling Station	9	4217	87
CG1	Vehicle Repair Workshop	3	2544	39
CH	Hotel	9	25442	534
CL	Public House	4	1244	53
CO	Office	66	85218	1954
CR	Restaurant	4	1094	51
CR1	Café	<3 so sample removed	-	-
CS	Shop	126	60681	1264
CS1	Bank	16	7861	369
CS5	Launderette	3	381	26
CS6	Post Office	7	4087	115
CS7	Showroom	3	2583	43
CW	Warehouse	10	14198	127
EL	School	31	80818	2165
IF	Factory	5	12446	120
IF3	Workshop	6	1483	61
LC1	Clubhouse	6	7948	270
	Total	**308**	**312245**	**7278**

3.6 Updating the SHU Appliances

As the SHU data were collected from premises predominantly in the early/mid 1990s, it was clear that the nature and distribution of some appliance types have changed in the intervening period. Amongst these changes two of the potentially most significant are the proliferation of computing equipment and the changes in non-domestic lighting equipment. The change in lighting was deemed to be likely to have an especially significant effect on the overall energy consumption of the non-domestic stock, particularly as its increased efficiency would have an effect on both heating and (where present) cooling. Also, almost all building spaces have some form of lighting, so the changes would be likely to affect large proportions of the stock floorspace. Similarly, the general increase in computing in almost all non-domestic premises types is likely to have increased consumption for this appliance group. Both appliance types play an important role when estimating internal gains (Jenkins, 2009).

3.6.1 Energy Consumption of Computers

Unless wattage was recorded specifically, the SHU survey methodology assumed the standard power rating of 130W for a computer and its associated display screen. In this research, this default value has been updated to 106W for all computer/display combinations recorded as being 130W in the original surveys. This 106W is based upon an average computer with an idle power rating of 73.8W (DEFRA, 2010b) coupled to an average LCD display rated at 32W (DEFRA, 2010a). Records of power ratings other than 130W were not altered, as these values were assumed to have been used to overwrite the default value and might therefore still be representative; for example, if an organisation chose to use either particularly high-powered, or low-powered computers. The load factor of all new computers was 1, and the load factor of existing computers was left unchanged.

3.6.2 Population of Computers in Office Rooms

Although nowadays computers appear in many situations, a decision was taken to update the population density of these appliances in Office rooms, only. The rationale for this approach was that Office rooms would account for the bulk of new computers and that this updating procedure would adequately reflect their proliferation since the 1990s. In the cleaned SHU data, computers appear in 1291 rooms, of which 508 are not Office rooms; however, 82% of computers appear in Office rooms. These statistics are obviously affected by the percentage of the SHU data made up of Office premises, but offices are also one of the most common room types in the data. Additionally, computer appliances are likely to be updated as new technologies appear, especially in Office rooms, where the computer is now a key tool in carrying out the room activity.

Analysis of Office rooms in the SHU data indicates that their mean area in Office premises is somewhat larger than for those in non-Office premises. However, where computers (PCs[*]) appear, their average population density is comparable between Office rooms in Office premises and Office rooms in non-Office premises; this is shown in Figure 3.2, below. In the figure, each box represents the middle two quartiles of values; the top of each upper line is the maximum and the bottom of each lower line is the minimum value.

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[*] Includes all desktop-scale computers, regardless of operating system.

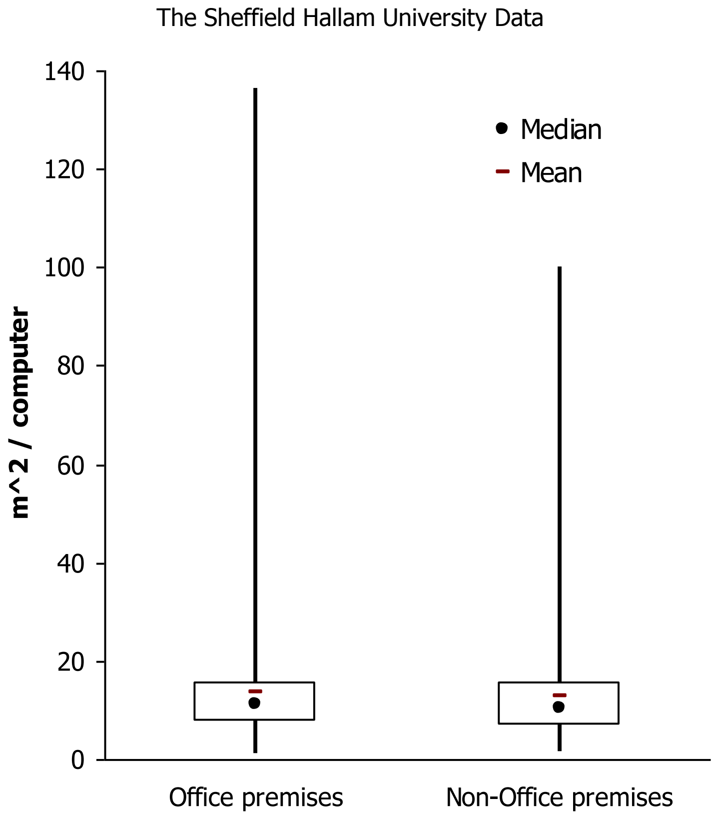

Figure 3.2: Distribution of floor area per computer in Office rooms, in Office premises and Non-office premises

The number of PCs in those Office rooms where none appeared, when the SHU surveys were conducted, needed to be updated to allow for the proliferation of PCs in the non-domestic sector. Figure 3.2 indicates that the density of PC populations does not vary significantly between Office rooms in Office premises and non-office premises. Across all Office rooms, the mean was found to be 1 PC per 13.25m^2, as shown in Table 3.5.

Table 3.5: Initial distribution of PC density in Office rooms – all premises types.

	Area per PC (m^2)
First Quartile	7.36
Minimum	1.21
Median	10.85
Maximum	136.50
Third Quartile	15.70
Mean	13.25
Standard Deviation	11.10

To represent current densities of PCs, the number in each Office room was updated by dividing the room's floor area by 13.25, to give a calculated number of PCs with an assumed minimum value of 1 per room. All other computing-related appliances were left unchanged.

Where, in the SHU data, Office rooms already contained one or more PCs (before the above procedure), the number of PCs was updated only if the area per PC was greater than one standard deviation above the mean, i.e. greater than 24.35m^2. This calculation is considered to give a fair representation of PC density, without condensing the spread of densities to an unreasonable extent. In no instance was the number of PCs reduced, as the number was deemed to have been recorded accurately and removal would compromise the integrity of the data.

In addition to the updating of the computer population, it was also necessary to attribute a usage pattern to these new appliances. This was achieved by taking the mean hours of usage and the mean utilisation factor for computers in each Primary Description type and applying these to the newly-created computers. Where computers already existed in rooms, but the number increased, the recorded utilisation factor was retained.

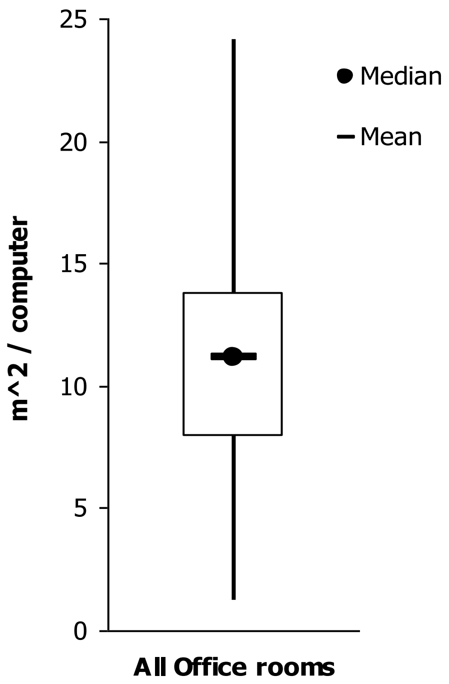

Figure 3.3: Distribution of floor area per computer in Office rooms, in all premises types, post density update

The distribution of population density of computers in Office rooms in the SHU data, at the end of the updating process, can be seen in Figure 3.3, above. The mean and median have moved closer together, and the long tail of the third quartile has been reduced, though there are still some rooms with low computer densities.

As a note, it was initially thought that replacing all typewriters and word processors might be relevant to the expansion of PC use. However, upon investigation of the cleaned SHU data, these two appliance types were found to be quite scarce, with only 165 typewriters and 6 word processors in the datasets. To save additional complication, these appliances were left in place, as their individual energy consumption was extremely low at an average of only 10.6kWh/yr each. This low energy usage scenario provides an interesting aside to the issue of the influence of PCs on energy consumption in non-domestic buildings, as the increase in the computer population results in a mode of electricity consumption that, although it existed in the 1990s, has not replaced consumption by other out-dated office equipment.

3.6.3 Population of Computers and Projectors in Schools

In addition to the office rooms, education facilities have also undergone changes in the population of computers in classrooms. The use of projectors and interactive whiteboards has also increased since the SHU surveys were conducted. As the majority of whiteboards are powered via low-powered USB connections, it was decided that the population of this equipment would not be updated.

A recent survey of the use of classroom whiteboards and projectors indicates that 90% of UK classrooms contain a projector and that they are used for 784 hours per year (Futuresource, 2010). Desk research, of a number of projectors aimed at the education sector, indicates that their average power rating is 280 Watts. So, the update of projector population has been applied by placing one 280W projector in each school room classed as "teach", with a load factor of 1 and utilisation factor of 0.9. This gives a yearly consumption figure of 198kWh in each of 541 rooms.

The methodology for updating the population of computers is similar to that applied to office rooms, but uses different sources of information. The trend of school computer populations has been extrapolated from data taken from a 2004 Department for Education and Skills report (Prior and Hall, 2004). This report contains data for the number of pupils per computer for the years 1998 – 2001 and for 2004. These data have been analysed to give an exponential trend line indicating that the average number of pupils per computer, in UK state schools in 2008, was 4.45. This seems reasonable and is converted to computers per pupil as a factor of 0.225.

The number of pupils per classroom has been calculated from data contained in Neufert (1980). Drawing values from tables in pages 120, 121, 125 and 126, describing space usage and occupation in a sample of 5 schools, the average area per occupant in teaching spaces is $3.72m^2$. To update the classroom computer population, it is assumed that the computers are distributed evenly across all classrooms (SHU Room Use "teach"). Each classroom's area has been divided by 3.72 (to give pupils per classroom) and multiplied by 0.225 (the number of computers per pupil), giving the number of computers in the classroom.

The population density of computers in schools has been sourced from data about schools, as opposed to individual rooms, so the number of computers in classrooms has been updated by overwriting the existence, or non-existence of computers in these rooms within the SHU data. As schools do not appear in the VOA SMV data, there is no subdivision of their floor area, so the uniform application of computer density can be used at the premises level, rather than at the Line Entry Level, as individual Room Uses become less significant.

3.6.4 Updating the Efficiency of Lighting

A search of literature has not revealed information about how the efficiency of real lighting in real buildings has altered in the period between the collection of the SHU data and the present day. Literature resulting from a survey of RICS building surveyors suggests that light fittings are, on average, likely to be replaced after approximately 22 years (BRE and RICS, 1992, page 30). In the SHU data, as shown in Table 3.6, the surveys were carried out over a number of years, with the greatest number (in the cleaned data) completed in 1994.

Table 3.6: Distribution of surveys (cleaned samples), by year and Primary Description

PD Code	Primary Description	Count of premises surveyed							
		1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
CG	Petrol Filling Station						4		
CG1	Vehicle Repair Workshop								
CH	Hotel					3			
CL	Public House	1	3						
CO	Office	4	33	1	8			6	2
CR	Restaurant	1	2	1					
CS	Shop	2	62	16	12	10	3	3	3
CS1	Bank			1	1		2	1	3
CS5	Launderette		1						
CS6	Post Office						2		
CS7	Showroom		2						
CW	Warehouse		1		6		1		
EL	School			1	7	16	2	2	
IF	Factory		1		1	1			
IF3	Workshop		1		2	1			
LC1	Clubhouse		1			2			

Amongst the data collected, there are some records for approximately when premises were last refurbished, but the term generally used is "recently", which makes it difficult to judge whether the premises should have their data updated to better represent current-day lighting equipment deployment; consequently, a systematic updating procedure was applied to all premises, regardless of information held on the date of surveys and refurbishment.

In view of the diversity of lighting appliances (92 variations) in the SHU datasets, and the specialised nature of some of the equipment, it was decided to only update the subclass of lighting used for "general illumination". In the cleaned datasets, this subset of appliances numbers 77 types, appears in most Room Use types, and applies to the bulk of floor area. To maintain the ability to analyse individual Room Use types in each premises type, it was decided that a simple updating procedure, using a percentage reduction in energy consumption per Room Use, was not suitable. The method decided upon was to update some of the lighting appliances, where they appeared, in each room in each of the premises.

To identify the appliances that would be likely to have the greatest effect on electricity consumption, the count of all lighting appliances was ranked and the most populous were updated. The procedure was then restricted to lighting types that constituted >1% of the sum of all lamps. Further constraints were applied by not updating compact fluorescent lamps (CFLs) and tungsten halogen lamps (TH). These classes of lamp were left unmodified, as it is less likely that they would be replaced: the TH lamps due to their more specialised uses (e.g. decorative lighting) and the CFLs because they are already efficient compared to most other lamp technologies. The general effect was to restrict the updating procedure to T12 (38mm diameter) and T8 (26mm diameter) fluorescent tubes, plus tungsten incandescent lamps equal to or greater than 25W and not greater than 150W.

The T12 and T8 lamps were all updated to T8 triphosphor lamps based upon the length of the tube; whilst the incandescent lamps were updated to compact fluorescent lamps of a similar light output, with integral control gear. The updated wattages were taken from lighting installation guidance (Action Energy, 2004, Table 1). The load factor, accounting for losses in control gear, was updated for lamps altered from T12 to T8, to reflect an assumed need to move to updated electronic ballast control gear in combination with T8 lamps. The new load factor of 1.05 was based upon lighting installation guidance (Action Energy, 2004, Table 1), being the mean of the difference between the lamp's consumption and its installed circuit consumption. The installed circuit wattage is affected by the number of lamps attached to each ballast, so an assumption was made that there was an equal split of lamps between single and twin installations. Existing non-T12 lamps did not have their load factors updated, as it was assumed that non-T12 installations were unlikely to have undergone replacement of control gear.

Although the main advantage of triphosphor lamps is their increased light output per Watt of input electricity, the number of lamps was not reduced. An assumption was made that improved lighting was achieved in preference to reduced consumption. The reasoning here is that as the datasets contained high proportions of T8 lamps, the updating process mostly resulted in the replacement of T12 lamps, which have a lower light output than T8 lamps. All instances of T5 lamps were left unchanged.

For the updating of incandescent lamps to CFL, a CFL of near-equivalent light output was substituted (First Light, 2011), hence the restriction of replacements to incandescent lamps between 25W and 150W. Details of the exact matches can be found in Appendix A. At the end of the updating process, new kWh/year values were calculated for the lighting appliances. The updated data were not again subjected to the filtering process described in Section 3.5, above.

3.7 Generating Profiles of Space Use in SHU Premises

Within energy benchmarking of entire premises, median values and quartiles are often used to represent consumption that is deemed to be typical; for example in TM22 (Field, 2006). However, in this research for the profiling of space use, the combinations of Room Uses in the SHU samples were found to be not consistent across premises, even within the same Primary Description (PD) category. That is, different combinations of Room Uses appeared in premises of the same type. As the space use profiles are intended to be used in conjunction with mean energy intensity values, the use of median values in the space use profiles could not be justified. Means were used instead, as these are likely to be adequately representative across the numbers of premises used in stock modelling.

To generate the profile of space use in a given PD category, the areas of all rooms of each use type were summed and expressed as a percentage of the total floor area of all premises in the PD category, thus generating an average percentage of total area used for a particular activity, within the sample. In addition to the profiles of average space use, box plots of the distribution of Room Uses were also generated, to demonstrate the spread of proportional area values within each Primary Description sample. Three categories of premises have been chosen to demonstrate space use profiles, in detail. The remaining categories are given in tabulated form in Appendix B.

The first of the three PD categories to be examined in detail is Shops. Within the cleaned SHU dataset, there is a total of 126 shop premises comprised of 27 Room Uses. Figure 3.4, below, shows how space is divided between the various Room Uses across the whole SHU shops sample. This profile is achieved by totalling the floor area for each Room Use and expressing it as a percentage of the summed areas of the 126 sample shops. The figure represents how space is used, on average, within the building stock of shops, assuming that the SHU sample is representative of the wider UK stock.

Figure 3.4 shows that although shops might be thought of as spaces for retail activity, they are in fact made up of many different Room Uses, or activities. If the SHU data are representative of the wider stock, it could be said that 40% of shop floorspace is not used for purely retail activity; for example, 17.2% of floorspace is used for storage, which is indirectly associated with retail activity.

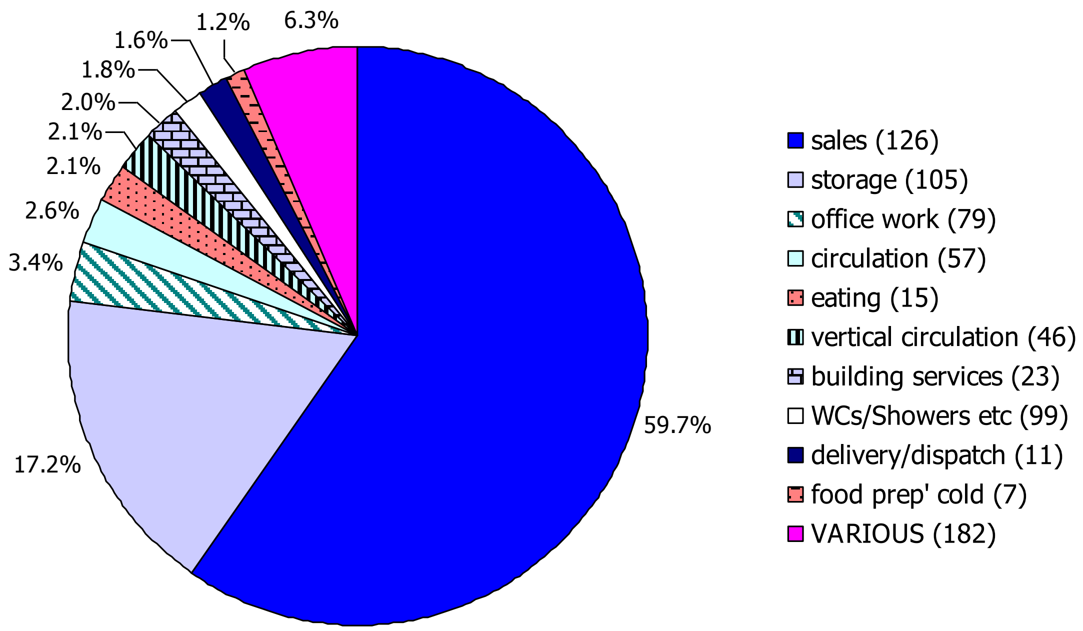

Figure 3.4: Total space use in shop premises, Primary Description code CS.

The "VARIOUS" category contains all remaining Room Uses that each represent less than 1% of the total area of the sample. This applies throughout Chapter 3.

The profile of space use in shop premises can be examined in more detail as shown in Figure 3.5, below. Here it may be seen that not all Room Uses appear in all premises, so Figure 3.4 shows us only how the stock appears, not how space is used in premises per Room Use.

In Figure 3.5, the titles on the *x* axis include the number of premises that contained the Room Use shown. The total sample size is 126 premises. Each *y* axis value is the percentage of floor area attributable to a Room Use within the premises in which it appears. This percentage may be spread across one or more rooms, within given premises. The yellow shaded boxes represent the middle two quartiles. The lines above and below the shaded box represent the upper quartile and lower quartile, respectively. The solid dot is the median value and the small circle is the mean value, for the sample of rooms. Note that this mean is not the same as the percentages given in Figure 3.4; the mean in Figure 3.5 shows the average percentage of floor area taken up by a Room Use in the premises where it appears, only. An example of the difference can be seen with rooms used for office work. The percentage of the total floor area of the SHU Shops sample used for "office work", as shown in Figure 3.4, is 3.4%. But for the Shop premises where "office work" is carried out, the mean floorspace is 10.3% of the total area, as indicated in Figure 3.5.

The figure indicates that where Room Uses appear in premises, their percentage of the premises' total area tends to be within a fairly restricted range. The space used for the core activity of "sales" has the greatest variability and the number of different types of Room Use is quite extensive.

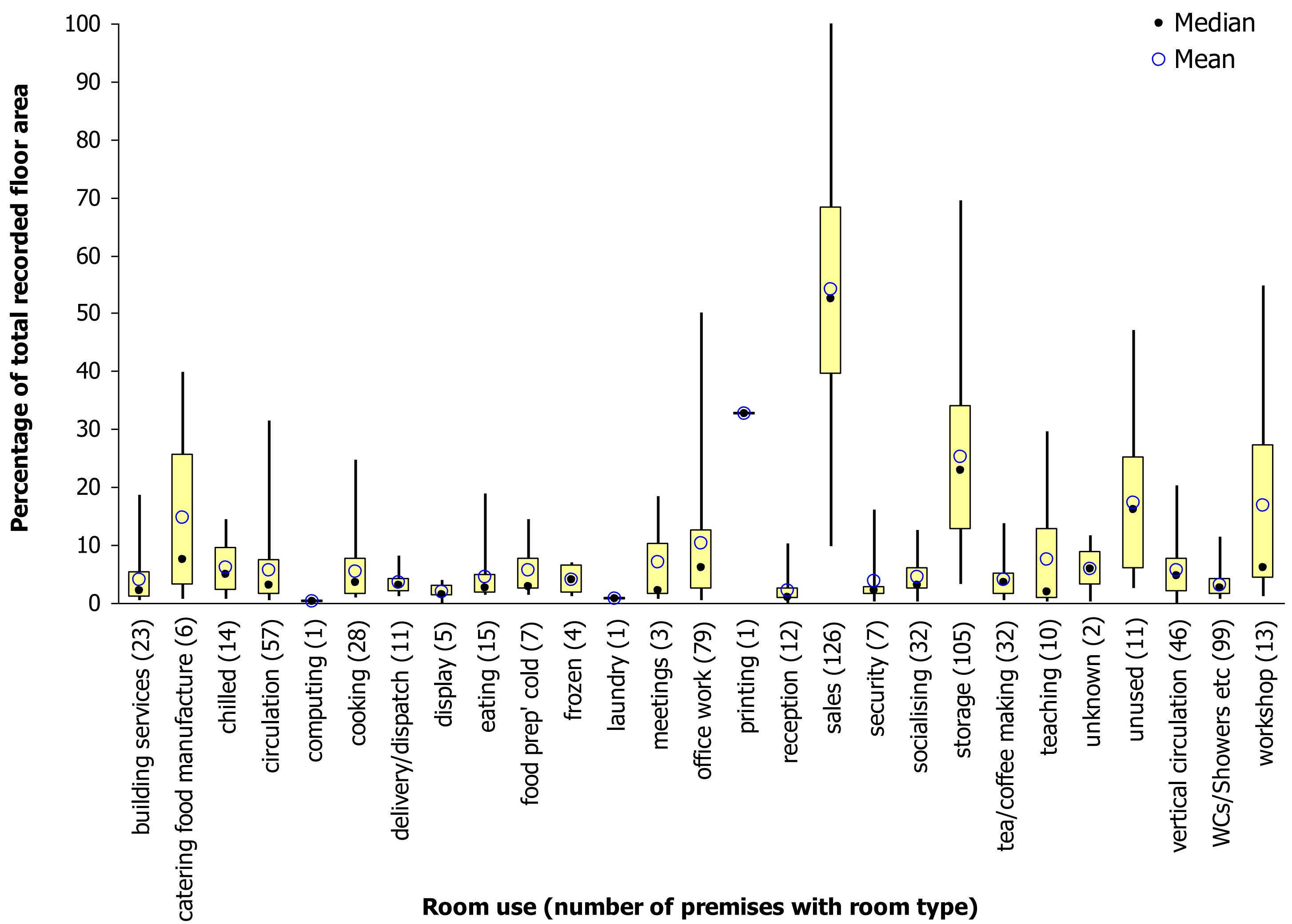

Figure 3.5: Distributions of space use in Shop premises, Primary Description code CS.

Below, Figure 3.6 shows the total use of space within the 65 Office premises in the SHU datasets*. As with the Shops sample, it may be seen that not all of the Office premises are in fact used for the accepted core function of the premises, i.e. "office work". In this case, 38% of the total sample area is used for non-office work.

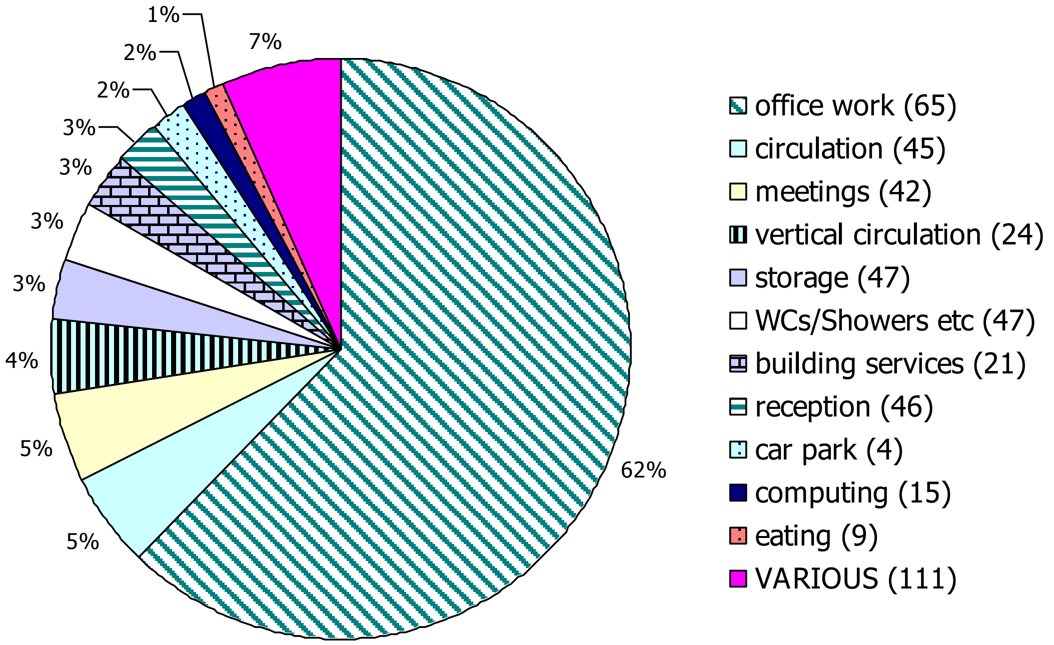

Figure 3.6: Total space use in Office premises, Primary Description code CO.

The distributions of how space is used, in Office premises, are shown in Figure 3.7, below. Here, there are 31 different Room Uses, but again the variability in the proportion of space used for a given Room Use is mostly quite small. In some room types, even where there are large sample sizes, the spread of areas can be very limited, for example in meeting rooms and printing rooms. However, as with the Shops sample, above, the greatest degree of variability is in what would generally be thought of as the core activity, i.e. office work. Also, as with sales areas in the Shop premises, the mean of office work areas in Office premises is very close to the median. The mean percentage of area devoted to office work (61%), per premises, is also close to the mean for the total sample (62%, as shown in Figure 3.6).

* Note that the colour scheme does not match Figure 3.4, as Room Uses differ. This also applies to Figure 3.8.

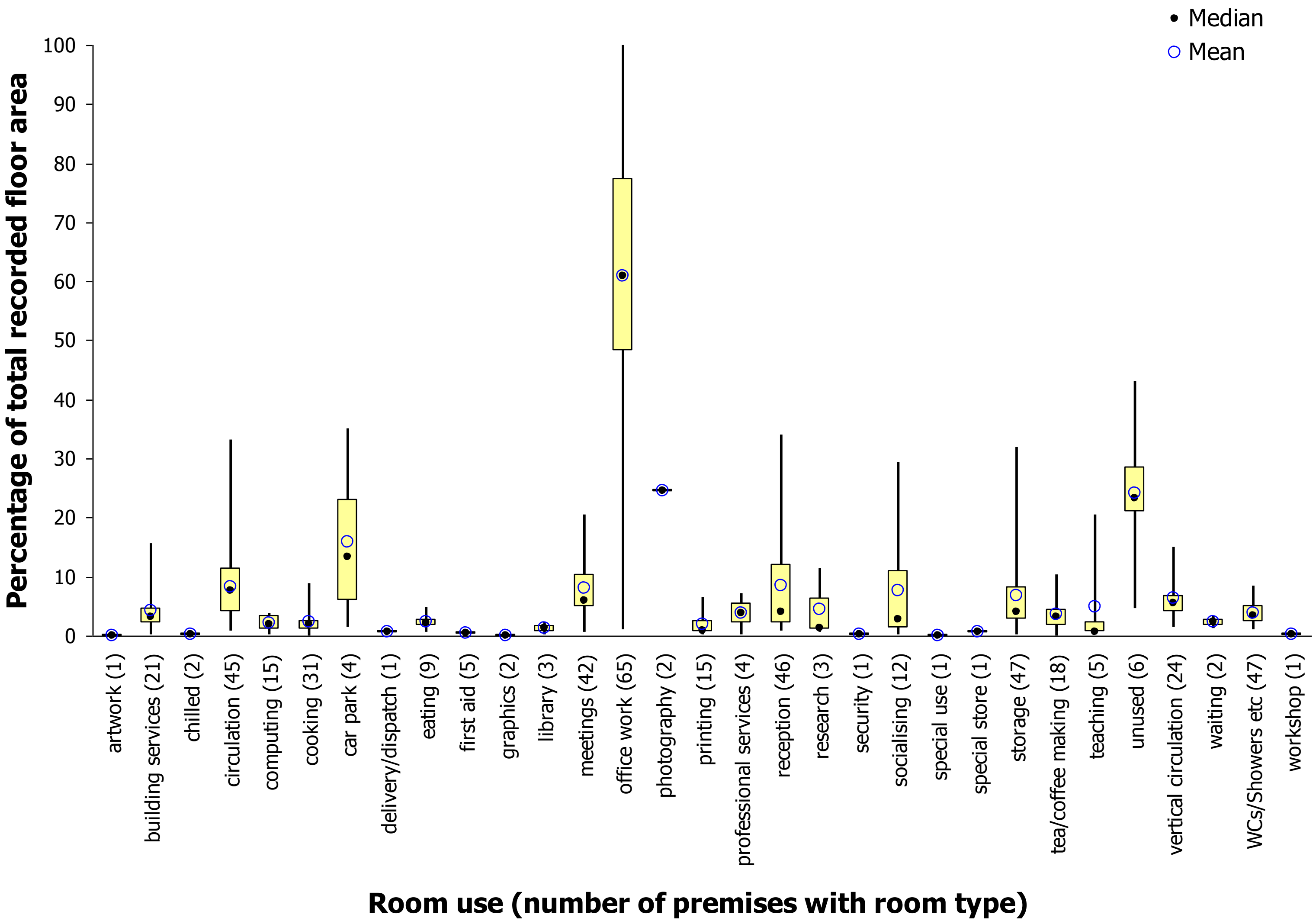

Figure 3.7: Distributions of space use in Office premises, Primary Description code CO.

The breakdown of space use in the SHU data's factory premises sample, is shown in Figure 3.8, below. After filtering, the sample size is only five premises but the variety of Room Uses is moderately large at 22 types, demonstrating the diversity of space use in this premises type. The spread of the proportion of each premises' area taken up by each Room Use, is essentially small, most-likely due to the limited number of data. The corresponding box chart gives little information and is omitted.

Access to more similar datasets, might help ascertain whether increasing the sample size increases the diversity of Room Use types. The Shops and Office samples, above, suggest that increasing sample sizes would reveal an increase in the variability of the proportion of space used for the core "process" Room Use, whilst the percentage of space used for support spaces is likely to be relatively unchanged.

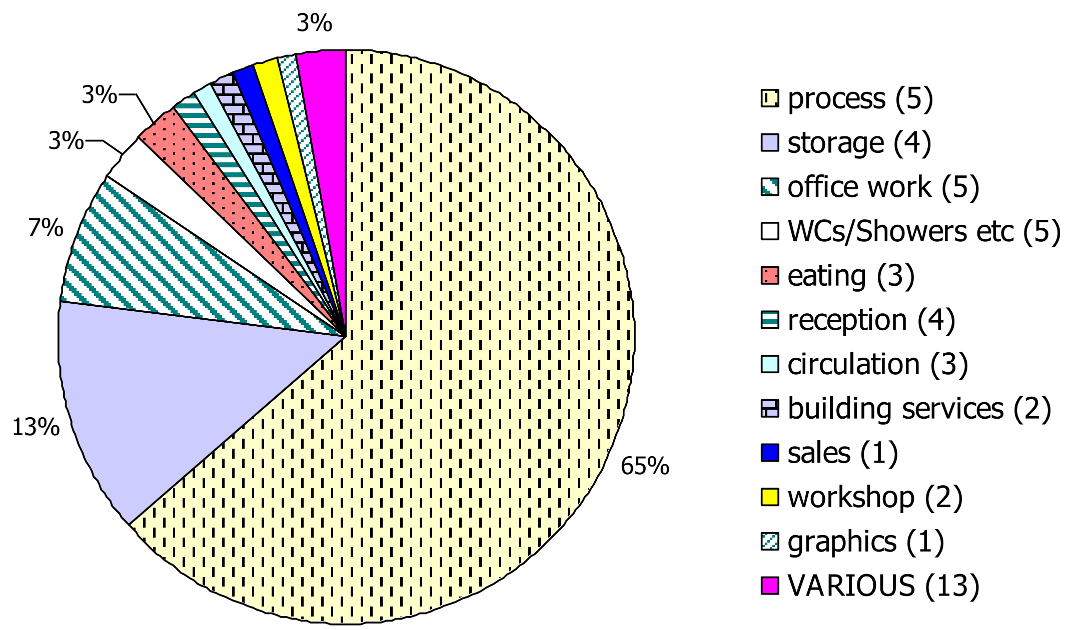

Figure 3.8: Total space use in Factory premises, Primary Description code IF.

3.8 Generating Profiles of Appliance Energy Intensity in SHU Premises

From the updated datasets, profiles of appliance Energy Intensity (kWh/m^2/yr), and thus consequent internal gains, were generated for each Room Use in each Primary Description class. These profiles are given in tabulated form in Appendix C. This section of the thesis presents the Energy Intensity (EI) profiles for each Room Use of the Primary Description classes Shops (PD code CS), Offices (PD code CO) and Factories (PD code IF).

Below, Figure 3.9 shows the distribution of Energy Intensity (kWh/m^2/yr) of electrical appliances per Room Use (together with the sample size of rooms), in Shop premises (PD code CS). The figure also shows the mean value of Energy Intensity (EI) and it can be seen that in some Room Uses the mean lies some way from the median and sometimes it also lies in the upper quartile. This mean is the mean of the sample shown and differs from the mean calculated from the total consumption of each Room Use divided by the total floor area of each Room Use, within a Primary Description class. The degree of variability in EI does not appear to have a simple relationship to the sample sizes of Room Uses. For example, "display" spaces have a wide spectrum of EI, with a sample size of only 6, whilst the 55 "building services" spaces have an even greater spread of values. Other Room Uses, such as "storage" have a predominantly small spread of EI values, but are affected by some instances of very high EI.

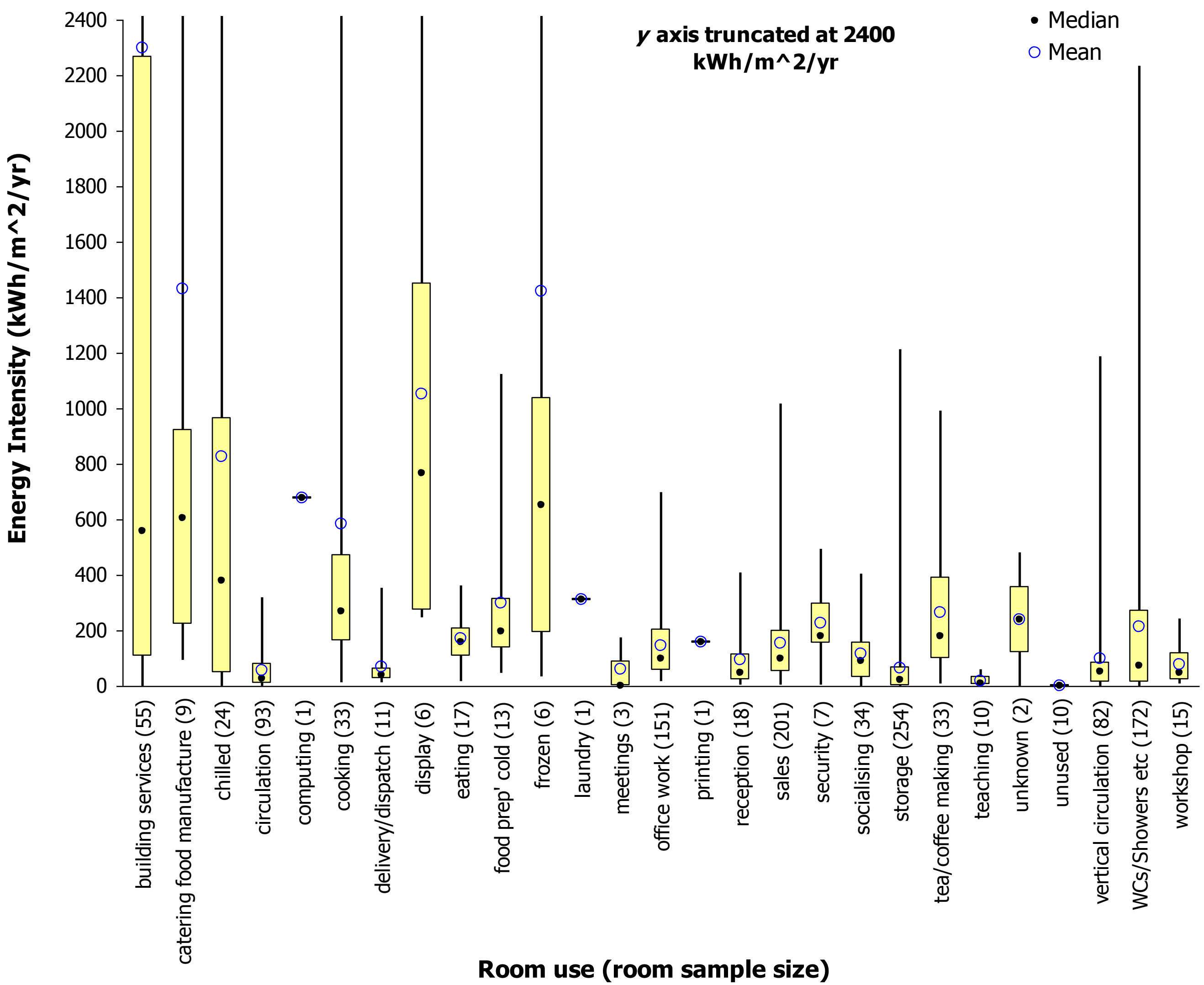

Figure 3.9: Energy Intensity, per Room Use, in Shop premises.

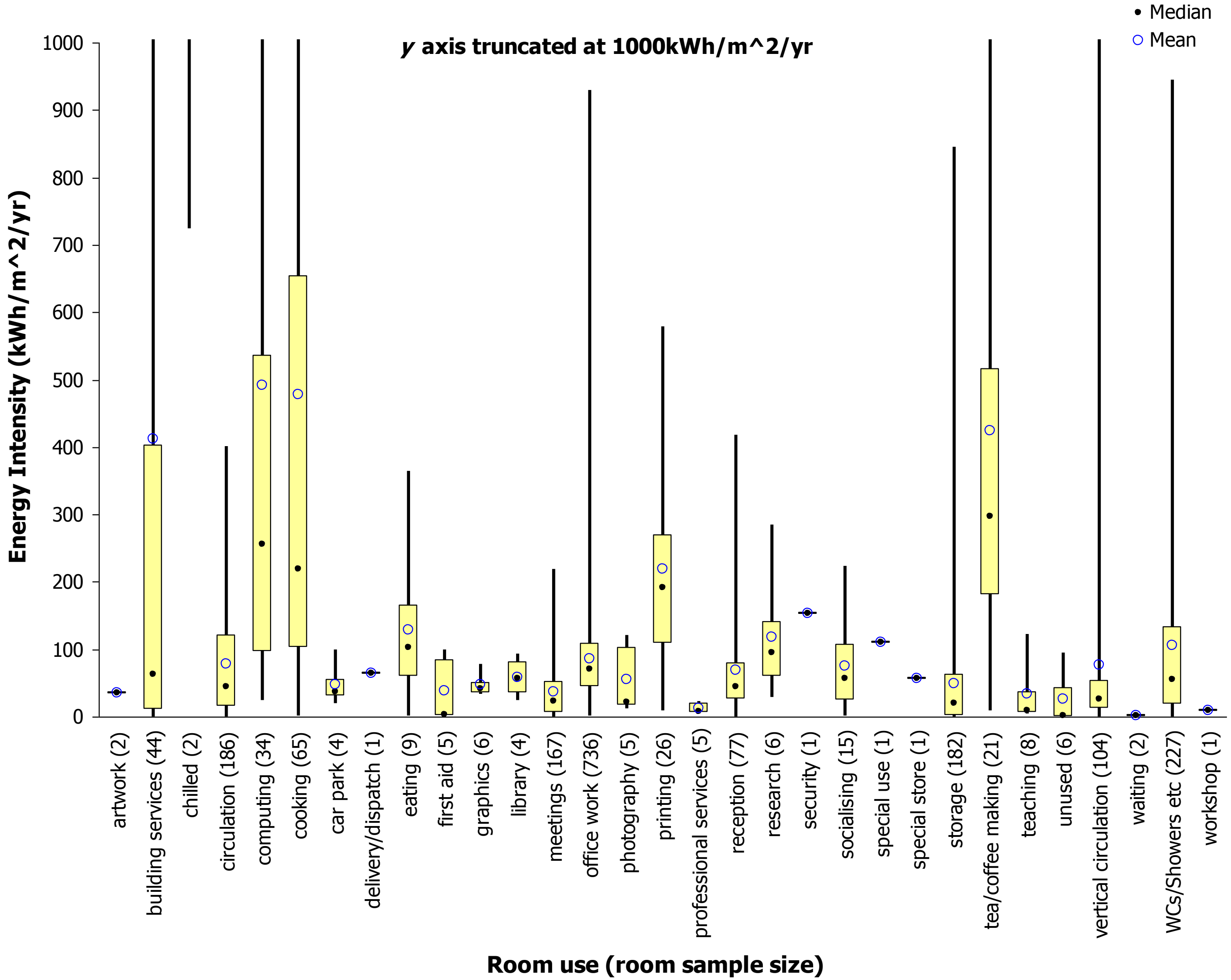

Figure 3.10: Energy Intensity, per Room Use, in Office premises.

The spread of EI in Room Uses, found in the SHU sample of Office premises, is displayed in Figure 3.10, above. As with the Shops sample, the middle 50% of values (the yellow boxes) are fairly compressed in some Room Uses, whilst in others such as "cooking" the spread is quite large. Again, there are several Room Uses that have their mean values skewed by a number of very high value outliers, for example "building services" and "computing". However, in most cases the mean EI is within the range of the middle 50% of data points.

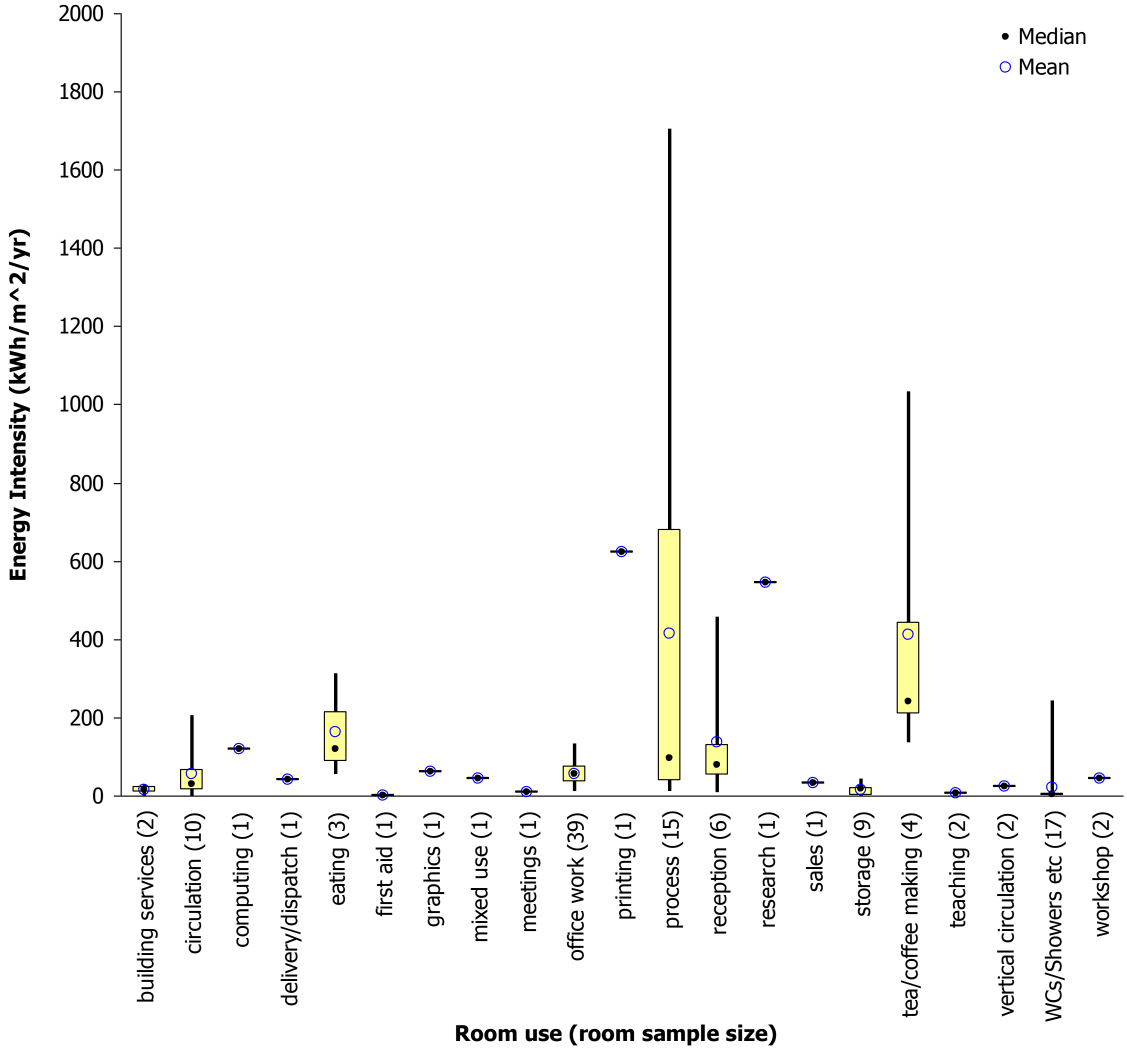

Figure 3.11: Energy Intensity, per Room Use, in Factory premises.

The sample size of Factory premises in the cleaned SHU dataset is only five premises and with 21 different Room Uses spread across these five premises, the sample size of some Room Uses is sometimes as low as one. These small sample sizes can be seen in Figure 3.11, above and some of the Room Uses (ignoring those with single records) have a restricted range of Energy Intensity values. This can be seen most easily in "office work" and "storage". Unlike the Shop and Office premises, there is considerable variation in the EI of the premises' core activity – in this case "process".

3.9 Generating Profiles of Electricity End Uses in SHU Premises

Energy meters record when, and how much, energy is consumed by the equipment on the downstream side of the meter. However, unless equipment is individually-metered, it is difficult to know where energy is being consumed, or what is consuming it. As the SHU data include records of the end use of the electricity consumption of each appliance, in each room, it is possible to generate profiles of electricity use by appliances in each room, sorted into the following End Use categories:

Lighting	Domestic Hot Water	Process
HVAC Controls	Fans	Telecommunications
Small Power	Computers	Computer Accessories
Catering	Lifts (elevators)	Pumps
Other	Unknown	

Figure 3.12, below, shows how the electricity consumption of appliances is divided between the various End Uses in each Primary Description sample. Lighting is the most noticeable contributor to consumption, with catering and process consumption being the other two large components. The high percentage of consumption allocated to the catering End Use dominates the Public House (CL), Restaurant (CR) and Clubhouse (LC1) premises and, considering this consumption is for electric appliances only, seems rather excessive. A more detailed examination of the Restaurant sample reveals that the sample premises are in fact fast food outlets and so might not be wholly representative of the stock population. One of the sample premises contains no gas-fuelled catering equipment whatsoever, making the sample potentially biased towards the consumption of electricity, not gas, for the catering End Use.

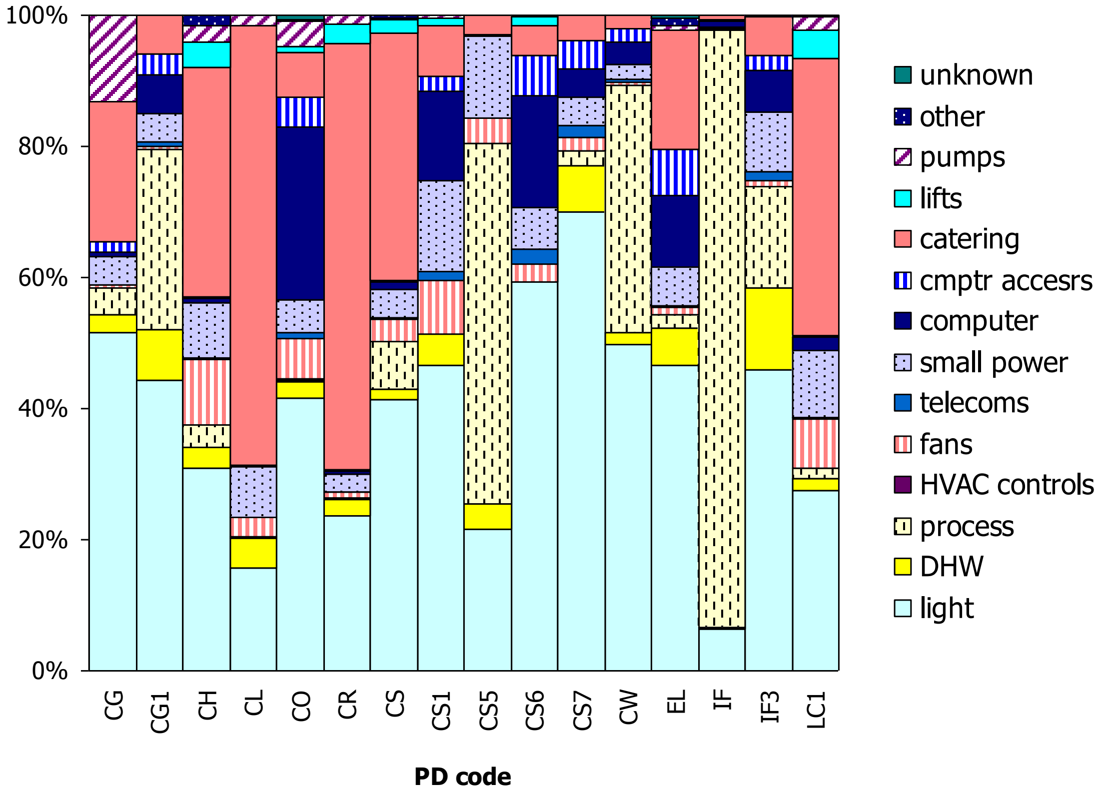

Figure 3.12: Breakdown of total appliance electricity consumption, per End Use, per Primary Description class.

To add granularity to the consumption analyses, this research has also disaggregated the consumption by appliances into End Uses, per Room Use, per premises type. Figure 3.13, Figure 3.14 and Figure 3.16, below, show how the electricity consumption, expressed as Energy Intensity (kWh/m^2/yr), of appliances disaggregates across each of the Room Uses within the Shop, Office and Factory Primary Description classes.

In the Shops class, the highest Energy Intensity (EI) is for "catering food manufacture" which, in the sample, is primarily bakery activities carried out in retail premises. Of greater interest is the "building services" category, where the End Use "catering" accounts for a large proportion of the EI. This is due to the refrigeration equipment, linked to chilled/frozen storage equipment located in the "sales" areas (Room Use "sal"), being located in the plant rooms of the premises. This situation effectively displaces the electricity consumption of this equipment, from the "sales" areas to the plant room, where internal gains are of less consequence.

Plant room areas, in Shops, are generally small (including in the Valuation Agency Office records), so the gains from refrigeration equipment will be accurately modelled from the Energy Intensity of building services areas. Where "refrigeration" appliances appear in "sales" spaces, they are most likely to be venting heat into those spaces and this thesis method enables these internal gains to be placed in the "sales" spaces.

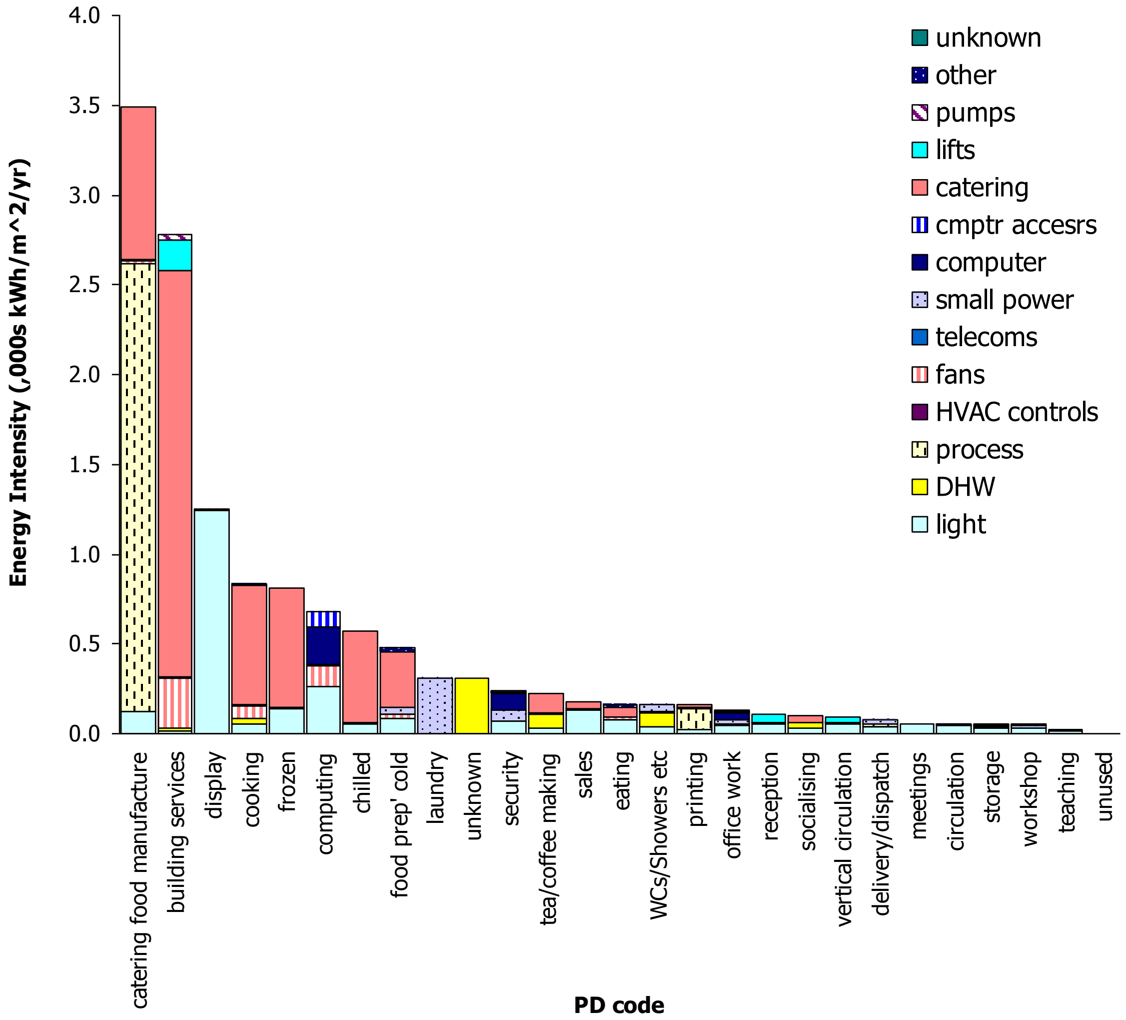

Figure 3.13: Energy intensity, per End Use, per Room Use in Shop premises.

The existence of domestic hot water (DHW) appliances can have a significant effect on the EI of some rooms. In "WCs/showers etc" the hot water produced appears to be mostly for use in the room containing the appliance, but there are also instances where DHW appliances are found in other room types (particularly "storage") where the hot water is likely to be used in other rooms. This situation often gives these rooms high EI values that should, in reality be spread across other rooms. A similar problem occurs where vacuum cleaners are attributed to small "storage" rooms, but are actually used in many other rooms. These effects have been ignored, as the overall floor areas of these room types are not very large in the VOA data, to which their EIs are to be applied and where these areas do appear, the consumption will be accounted for.

Figure 3.14, below, presents the Energy Intensities of Room Uses in the SHU sample of Office premises. The most noticeable component of consumption is the EI of "chilled" spaces. In reality, there are only two rooms that fall within this category in the sample. One of these rooms is used for the storage of food, but the second is used "for samples" storage, in the Office premises of a regulatory body and is thus not used for catering purposes; in essence this is a "process" End Use. However, the "for samples" storage accounts for only 25% of the total consumption of this Room Use and has a much lower EI, than the room used for catering chilled storage.

To improve clarity, for other Room Uses, Figure 3.15 (page 81) shows the breakdown of consumption by End Use, in Office premises, excluding the Room Use "chilled".

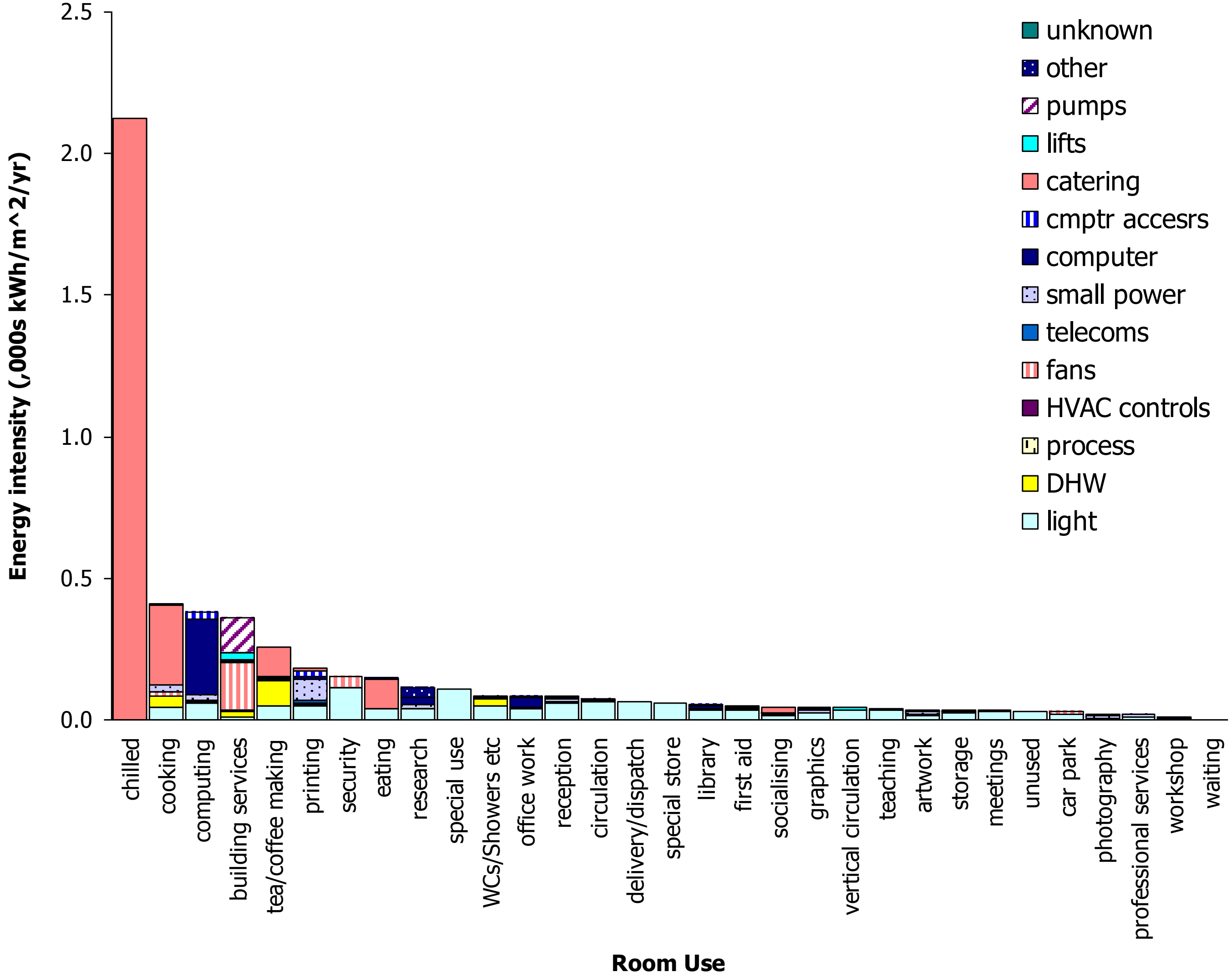

Figure 3.14: Energy intensity, per End Use, per Room Use, in Office premises.

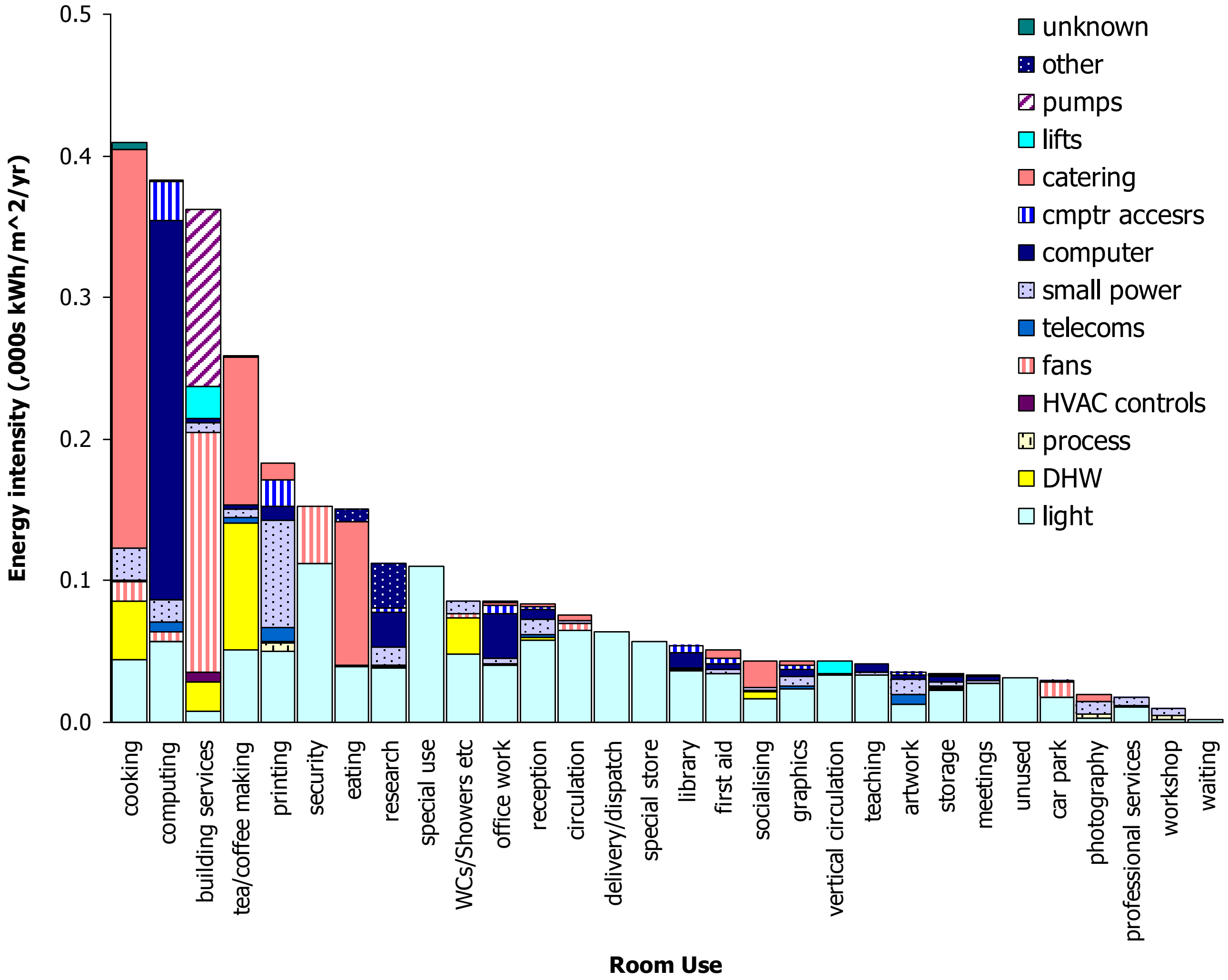

Figure 3.15: Energy intensity, per End Use, per Room Use, in Office premises. Excludes Room Use "chilled".

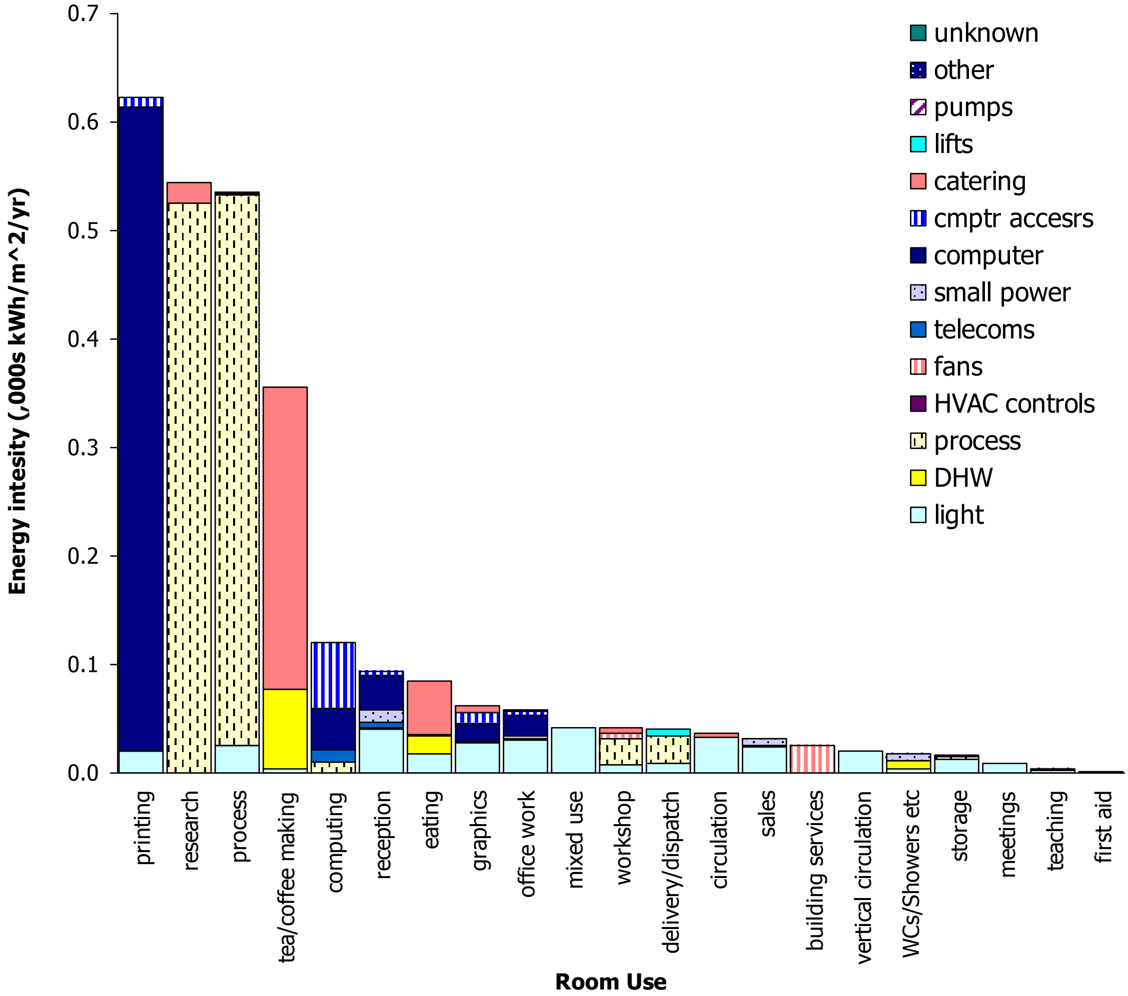

Figure 3.16: Energy Intensity, per End Use, per Room Use, in Factory premises.

The End Uses of appliance electricity in the Factory class, as shown in Figure 3.16, are not straightforward. The high EI of the "computers" End Use component of "printing" rooms is particularly prominent. Investigation of the data show that there is only one "printing" room in the Factories datasets and that this room contains a single computer of 10kW, running all the time but with a utilisation factor of 0.1, making its overall power consumption rate 1kW. This is the highest rate of consumption of all computing equipment in the cleaned SHU data – the nearest such power rating being 500W. The EI of this "printing" room is the highest value of all such rooms, but it is only 44kWh/m^2/yr greater than its nearest equivalent. Also, the "printing" room represents only 0.12% of the total floor area of the Factories sample, so is unlikely to have a marked effect upon the overall consumption characteristics of Factories in a model.

3.10 Defining What Equipment is Used For

In addition to the End Use codes described above, the SHU datasets also include a "Used For" code for each equipment record. There are 57 codes and corresponding descriptions to describe the activity for which an item of equipment is used. Three of these descriptions are of limited use – "balancing figure", "other", "special" and "unknown" – and the "balancing figure" category is excluded hereon. Due to the diversity of combinations of equipment and Used For codes, the remaining 56 codes have been aggregated into 17 groups, to represent classes of activity, for which the equipment is used. The full list of the Used For codes, their descriptions and the activity group to which they have been allocated can be found in Appendix H. The Used For groups are:

Process	Catering	Sales
Office work	Learning	Entertainment
Specialist	Illumination	Refrigeration
Telecoms	DHW	HVAC
Transport	Pumps	Facilities
Other	Unknown	

Figure 3.17, below, shows the profiles of consumption, per Used For group, for each Primary Description class sample. Here, as with the End Use profiles above, the importance of consumption for illumination can be seen very easily, together with catering and, in some PD classes, process.

Analysis according to the Used For groups, suggests that these may enable an improved view of the patterns of consumption in premises and their Room Uses. This can be seen most easily in the percentages of consumption for "catering" and "refrigeration", in Restaurants (PD code CR). The consumption Used For "catering" far exceeds that for "refrigeration", highlighting the effect of one of the sample Restaurant premises having no gas-fuelled catering equipment. In the Public House (CL) category, the consumption of "refrigeration" equipment, significant for the chilling of drinks, can be seen clearly, in Figure 3.17, compared to Figure 3.12, showing End Uses. However, in Figure 3.17, the consumption Used For "refrigeration" seems slightly low, in Public Houses.

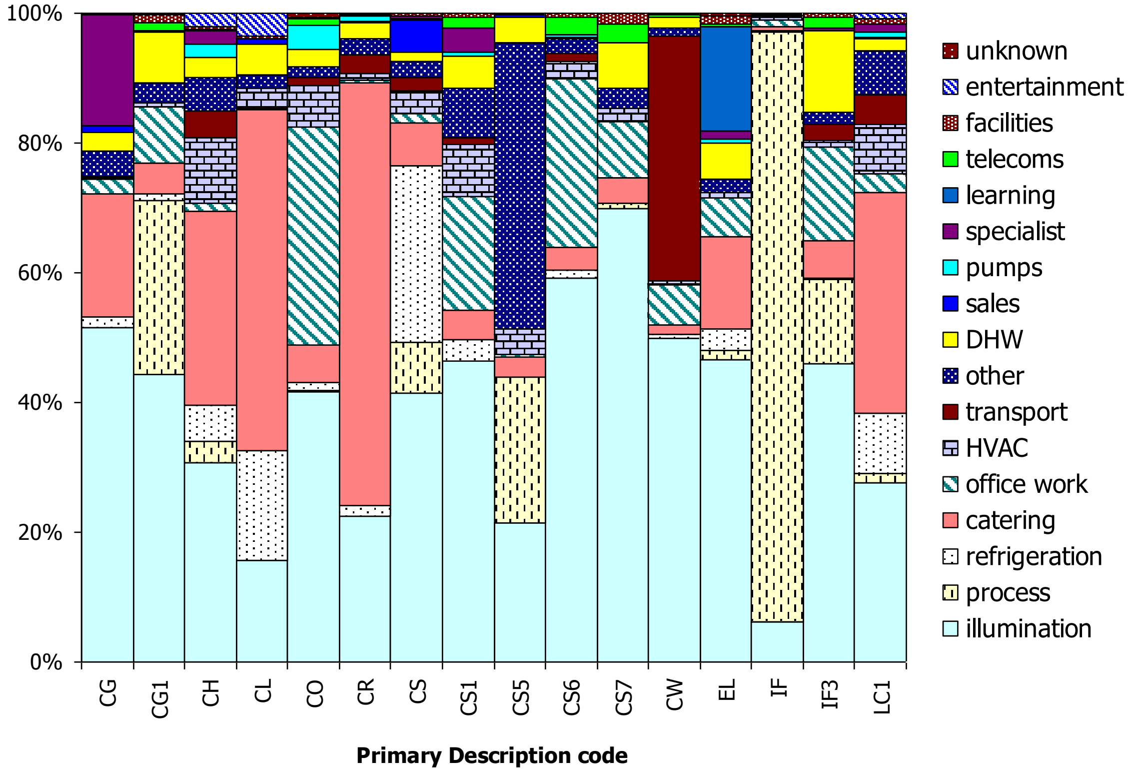

Figure 3.17: Breakdown of total appliance electricity consumption, per Used For group, per Primary Description class.

The Used For group "office work" provides a useful indicator of the amount of electricity being used across various premises types, for what is likely to be (essentially) the same nature of activity. As expected, Office premises have the highest percentage of their consumption Used For "office work", but Post Office premises (CS6) are not greatly dissimilar.

The profile of consumption by Used For groups, in Shop premises, is shown in Figure 3.18, below *. The principal difference between the analysis of consumption by End Uses and Used For groups, in Shop premises, is also seen in the separation of the Used For group "refrigeration" from the End Use "catering". The REMAINDER group constitutes barely 1% of the total.

* Note that the "REMAINDER" category contains all Used For group consumption that individually does not exceed 1% of the sample's total consumption.

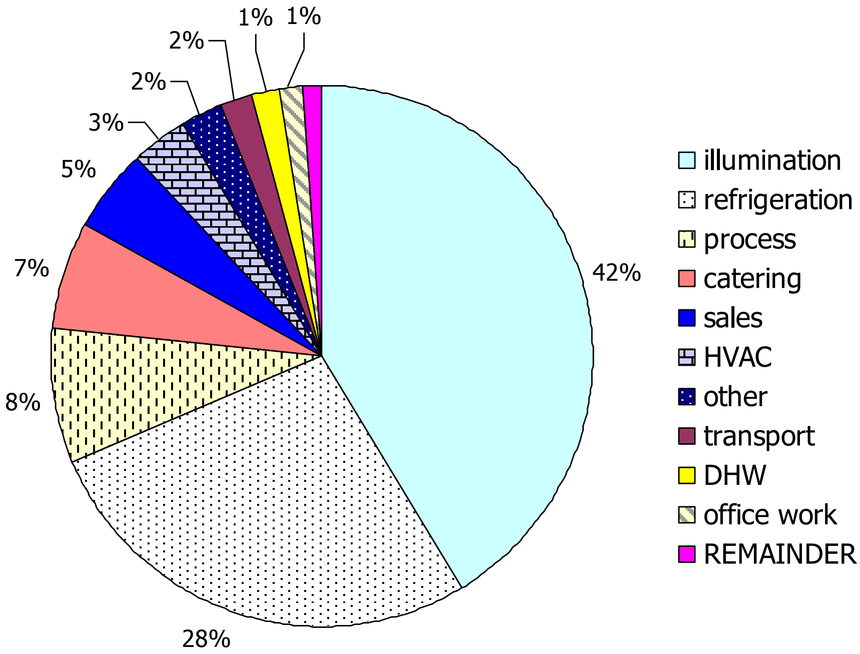

Figure 3.18: Appliance consumption, by Used For group, in Shop premises.

To add detail to the Shops profile, the Energy Intensities for each Room Use, subdivided by Used For groups, are shown in Figure 3.19, below. Here it may be seen that much of the appliance consumption in the building services Room Use can be attributed to the Used For group "refrigeration", thus indicating that the End Use "catering" (Figure 3.13) is mostly refrigeration and occurring in plant rooms.

In terms of energy intensity, the Room Use "sales" is the 13th most intensive, but, as Figure 3.20 indicates, due to its large area, it is the greatest consumer of appliance electricity.

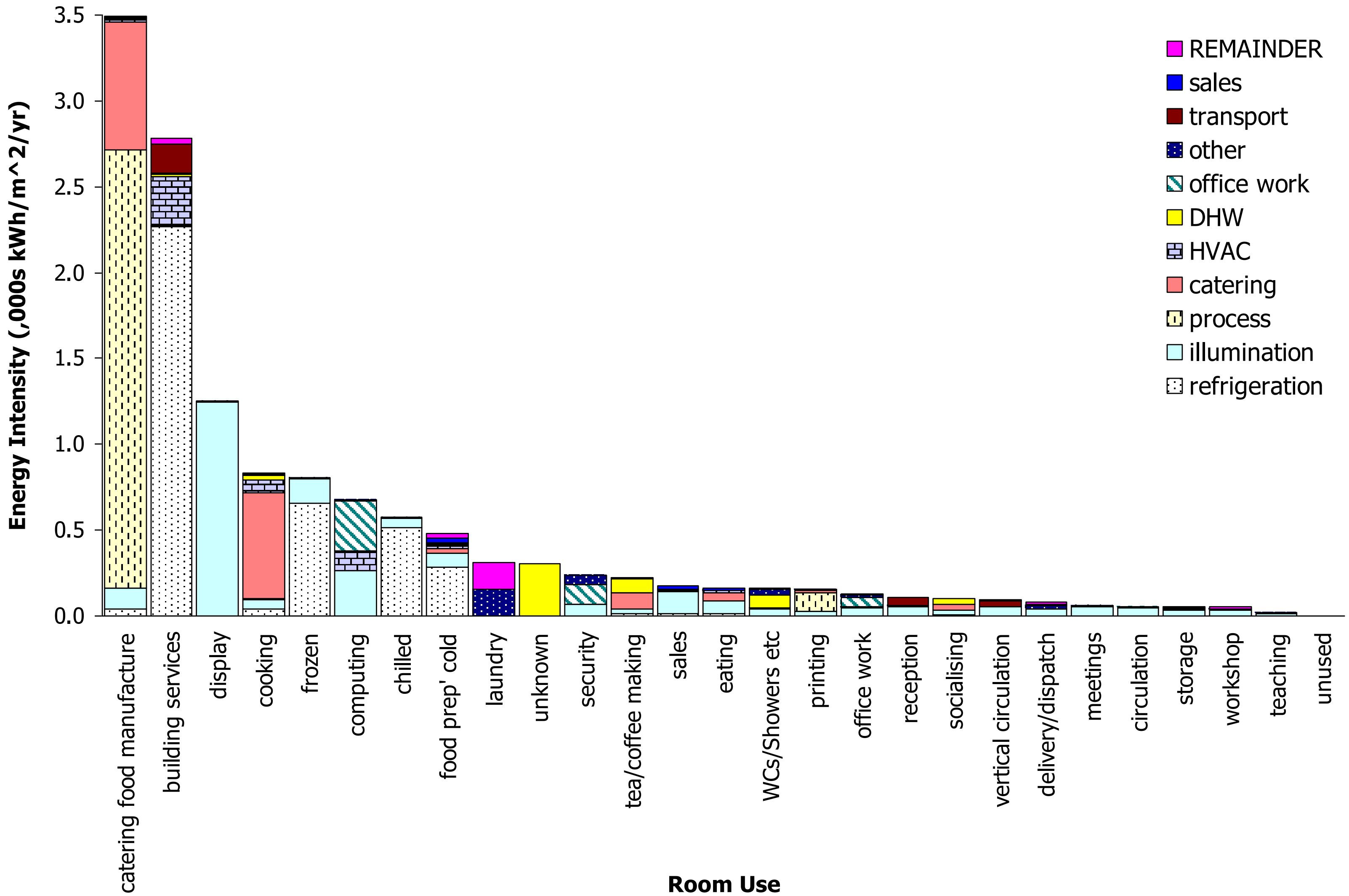

Figure 3.19: Energy intensity, per Used For group, per Room Use in Shop premises.

Figure 3.20, below, presents a summary of the Room Uses and Used For groups, and their total consumption within the SHU Shops sample, demonstrating how illumination is the predominant user of electricity. The consumption within building services areas is mostly made up of uses attached to refrigeration. Note also, that these Shop premises contain process activities, with a considerable level of consumption that might not normally be categorised as such when using a whole premises approach to energy modelling. The "VARIOUS" category on the *x* axis contains all Room Uses for which the summed consumption of each individual type does not exceed 1% of the sample's total consumption.

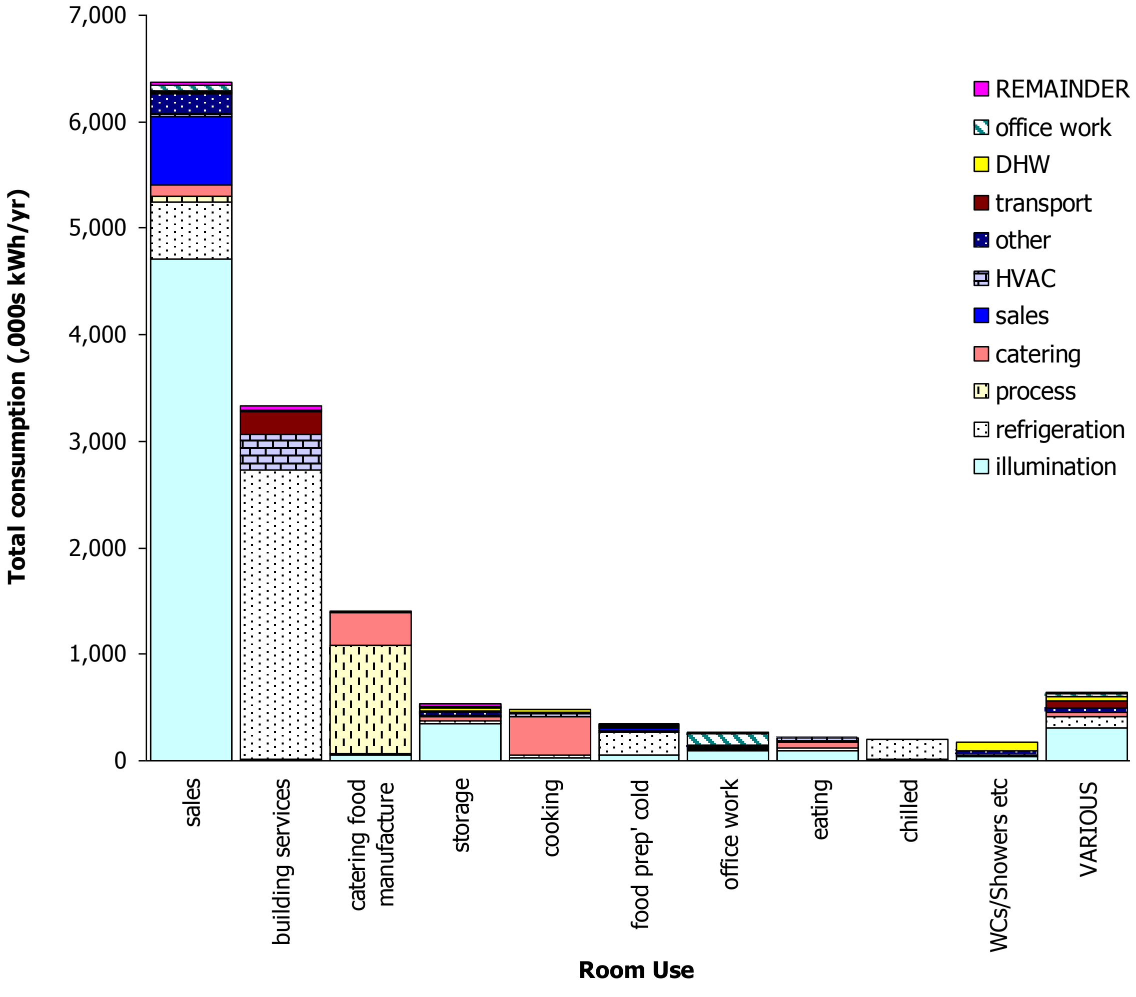

Figure 3.20: Total consumption per Used For group, per Room Use, in Shop premises.

Below, are the energy intensity and total consumption profiles of the SHU Office premises sample, categorised by Used For group and Room Use.

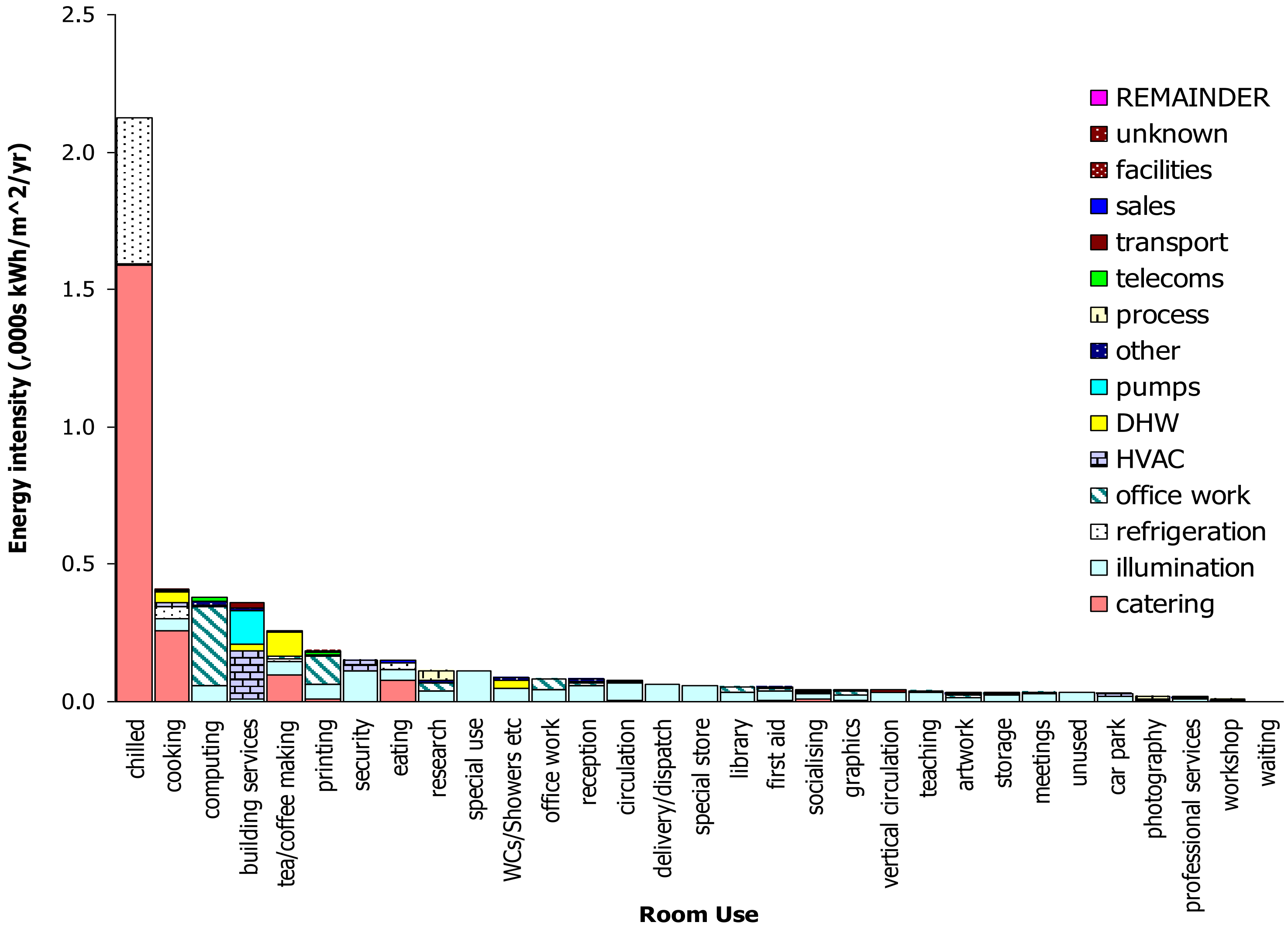

Figure 3.21: Energy intensity, per Used For group, per Room Use, in Office premises.

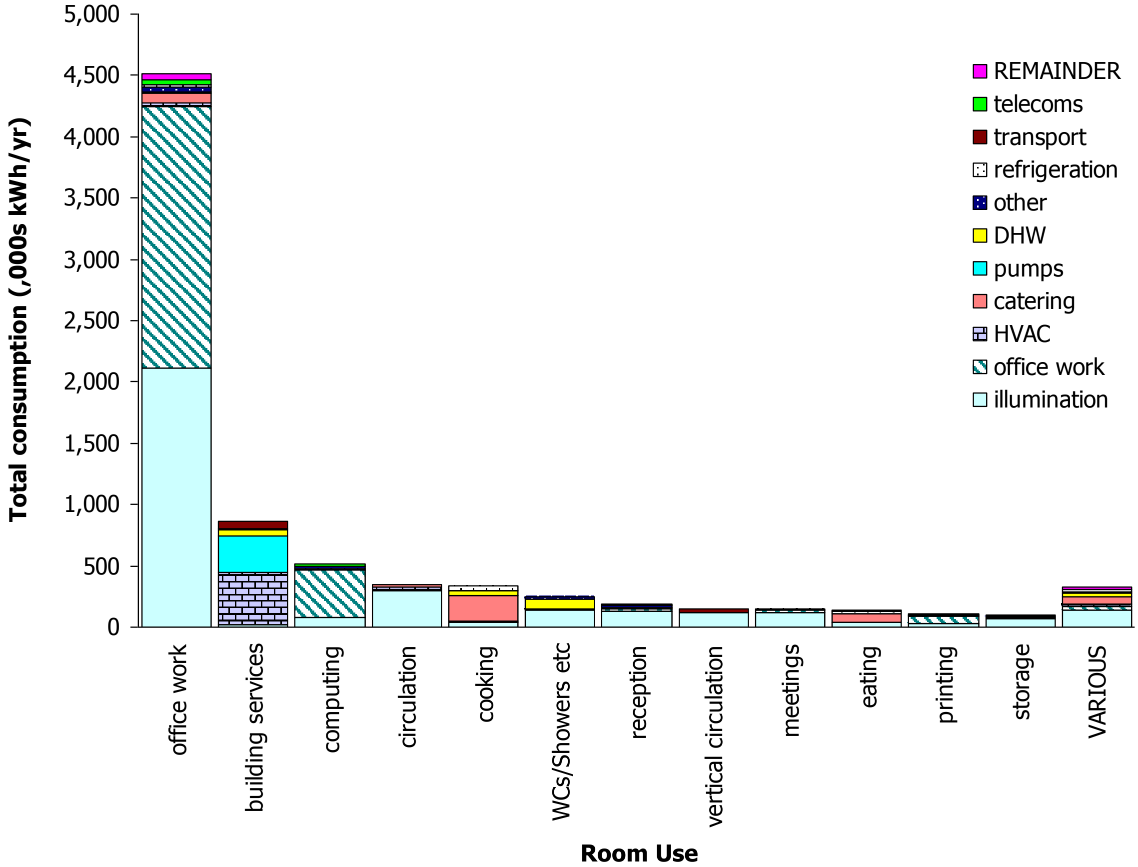

Figure 3.22: Total consumption per Used For Group, per Room Use, in Office premises

Figure 3.21 and Figure 3.22 show how Office premises have a diverse spread of appliance electricity uses. The range of energy intensities is not as great as that of Shops and the principal Room Use, "office work", consumes electricity overwhelmingly for the Used For groups "office work" and "illumination". Only the Room Use "chilled" stands out as exceptional, but this is not a significant user of electricity, in overall terms, as indicated by Figure 3.22, where its consumption is so little that it is aggregated into the "VARIOUS" category: this is due to its small floor area.

Although the "chilled" Room Use is indicated as having electricity used for "catering", this is probably incorrect, as one of the two rooms in the sample is used for the storage of "samples". So, even though the End Use of all of the consumption is listed as "catering" (Figure 3.14), the Used For group classification still does not completely attribute the electricity consumption. This may also be the case in other instances, but this has not been investigated in detail.

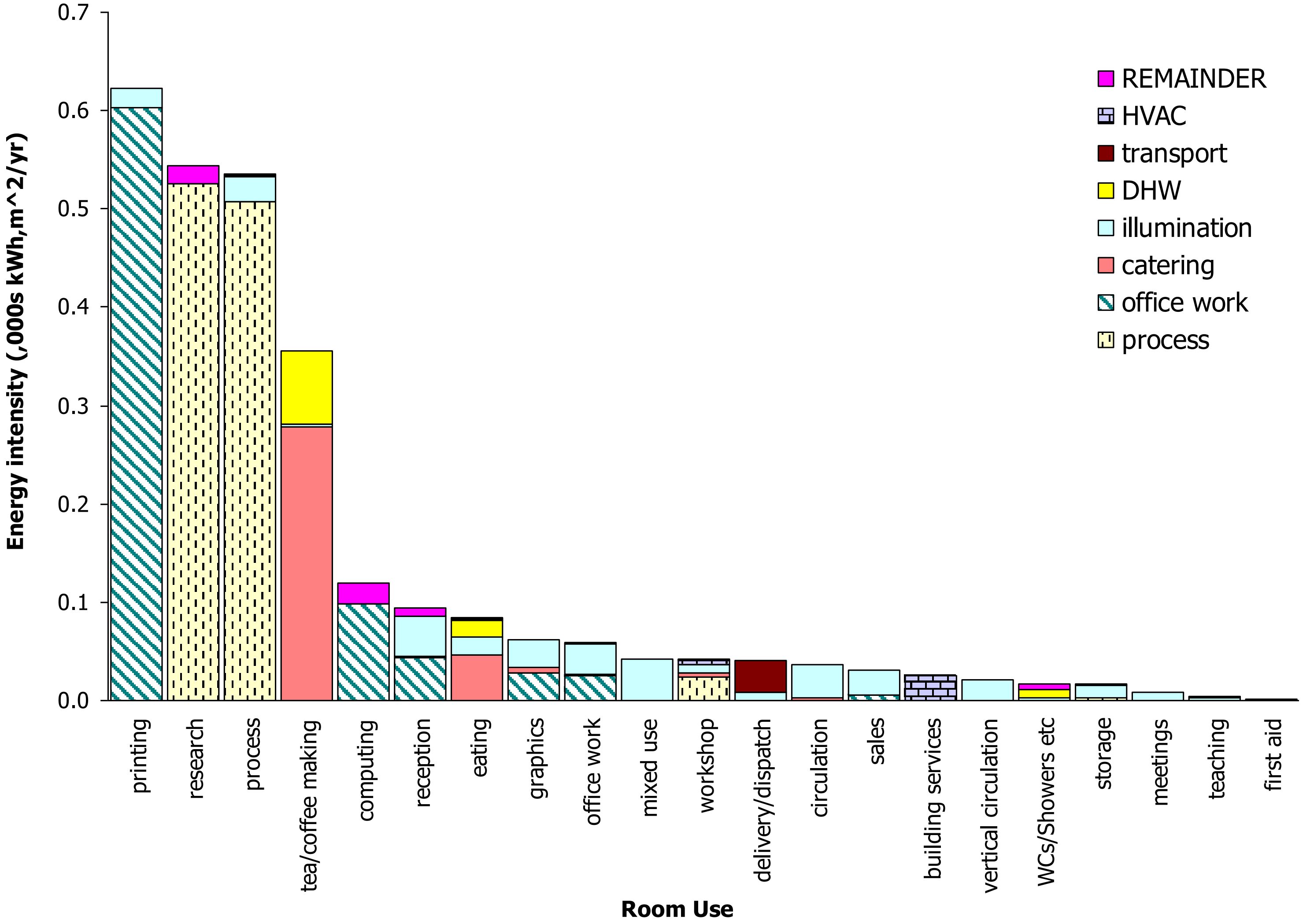

Figure 3.23: Energy intensity, per Used For group, per Room Use, in Factory premises.

Figure 3.23 and Figure 3.24 show that although there are a number of different Room Uses and Used For groups applicable to Factory premises, in the SHU sample, the combination of the "process" Room Use and the "process" Used For group completely dominates the premises' consumption profile. The proportion of consumption attributed to "Process" and "Illumination" is so great that all other Used For groups are barely visible on the figure.

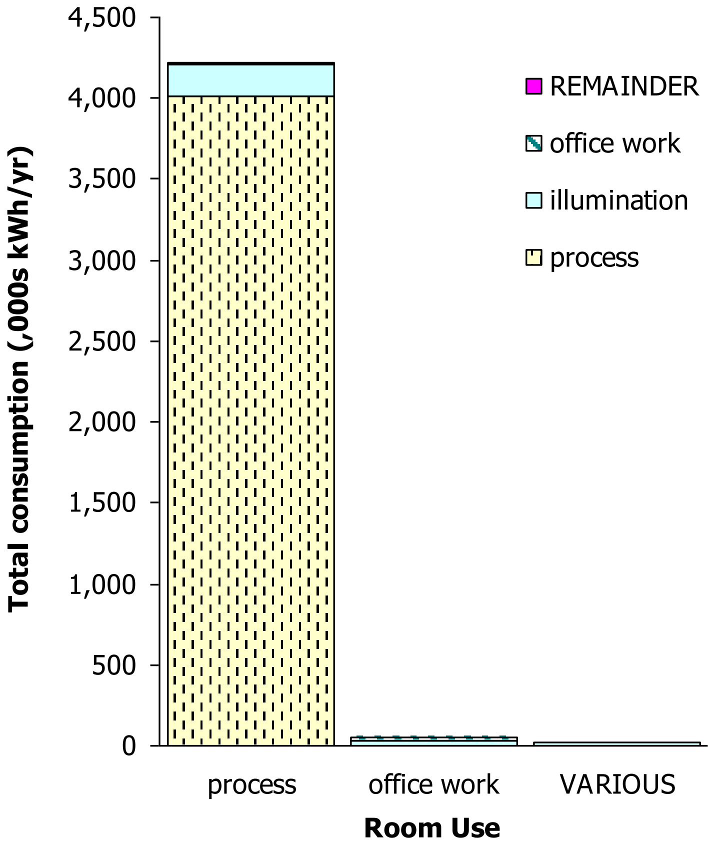

Figure 3.24: Total consumption per Used For group, per Room Use, in Factory premises

This situation is to be expected, due to the majority (65%) of floorspace being classified as the "process" Room Use. The importance of "process" areas is continued, even when the "process" Used For group is excluded from the analysis of consumption, as shown in Figure 3.25, below.

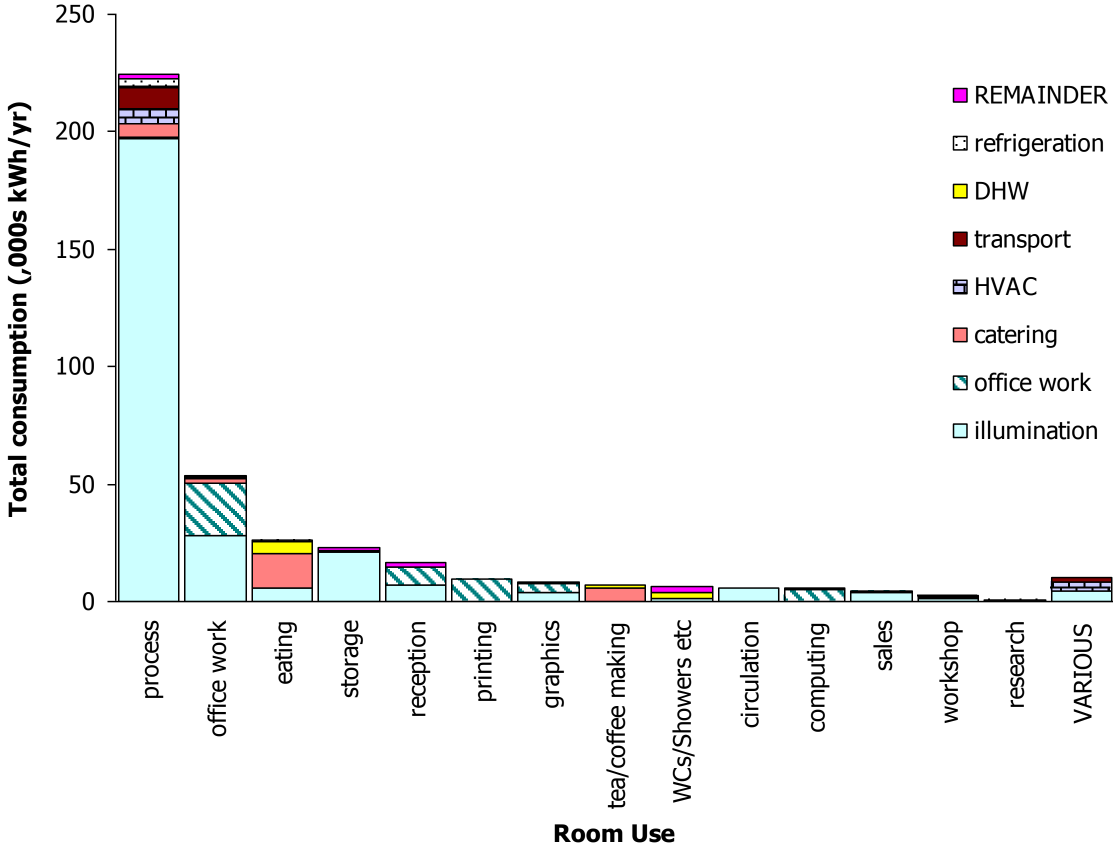

Figure 3.25: Total consumption per Used For group, per Room Use, in Factory premises, excluding the "process" Used For group.

After the removal of the "process" Used For group, "illumination" is the main consumer of electricity, with "office work" and "catering" also becoming more significant, though "catering" is restricted to small areas. Note that the "transport" Used For group includes the consumption attributable to the movement of goods within premises – for example, fork lift trucks and associated appliances.

Notice should also be taken that the "process" Used For group – as with all other such categories – does not include any equipment or activities powered by fossil fuel. This highlights the importance of the levels of energy consumption for process activities in Factory, or similar, premises.

3.11 Discussion of Analysis of the SHU Data

The analysis of Room Uses in each premises type indicates that premises of the same Primary Description code do not all contain the same range of Room Uses. This finding can be coupled to the finding that the Energy Intensity of appliance electricity consumption is different for each Room Use, to help explain the varying levels of consumption of premises within a given Primary Description code (after normalisation for floor area), found in the real world.

The usual method of modelling stock energy consumption, per premises, homogenises the total floor area and ignores the existence, or non-existence of particular Room Uses when calculating space use and applying Energy Intensity to the space. This research takes the Energy Intensity of Room Uses, together with the End Use and Used For profiles from the SHU data and applies them to the activity subdivisions of premises in Valuation Office Agency datasets, as will be shown in Chapter 4. Using this methodology increases the subdivision of premises, identifies the use of space more specifically and allows a more specific Energy Intensity to be applied to the space, and consequently the premises and the stock.

The SHU sample sizes of premises types were, in most cases, reduced by the filtering processes applied to them. However, as this research is concerned with identifying patterns of energy consumption for the activities performed in area subdivisions of premises, the number of premises Rooms is actually more important than the number of premises in the samples. In general, the number of rooms, per Primary Description and Room Use combination, was deemed large enough to extract data that could be used for inferring appliance electricity consumption in stock modelling, in view of the restricted number of data that are accessible.

The analyses of the SHU data also suggest that the percentage of premises' total area used for some activities is fairly consistent. This is particularly the case for activity spaces that are essential but non-core support spaces, such as "WCs/Showers etc", "circulation", "reception" areas and "building services" areas. It is in the floorspace used for the core activity of premises – such as "office work" in Office premises – that greater degrees of variability occur. Indeed, in some premises of the sample, the area devoted to the core activity is small, sometimes apparently nil. For example, there are Office premises that contain no "office work" rooms, but instead have "graphics" rooms. Within the VOA Primary Description classification system, these premises are still likely to be Offices, but it is not clear whether the "graphics" rooms (or similar) in the SHU classification system would be classed as such in Line Entries, by the VOA (see Section 4.4.2.3). The suggestion is that, in terms of the proportional use of space, larger sample sizes increase the degree of variability – particularly of the core activity. Non-core support spaces tend to have areas that are closely tied to the overall areas of premises.

The analyses of Energy Intensity (EI) suggest that as sample sizes increase, the degree of variability decreases, within each Room Use. Figure 3.26, on page 95, shows how the EI of spaces used for "office work" are mostly held within a fairly narrow band of values, with the mean falling between the first and third quartiles. "Sales" spaces are subject to greater variability, but their EI is still moderately restricted. "Storage" spaces have a very limited distribution of EI, but due to a number of extreme outliers, the mean is slightly above the third quartile. The existence of vacuum cleaners and electric appliances providing Domestic Hot Water (DHW) has a marked effect on the EI of such spaces.

The EI of spaces used for non-core support activities, such as circulation spaces and WCs/Showers etc, are mostly contained in a narrow band of values; again outliers are often affected by the existence of DHW appliances. An exception to this general observation on support spaces, is "building services" areas. In these, there is a high degree of variability, affected by a number of high EI outliers.

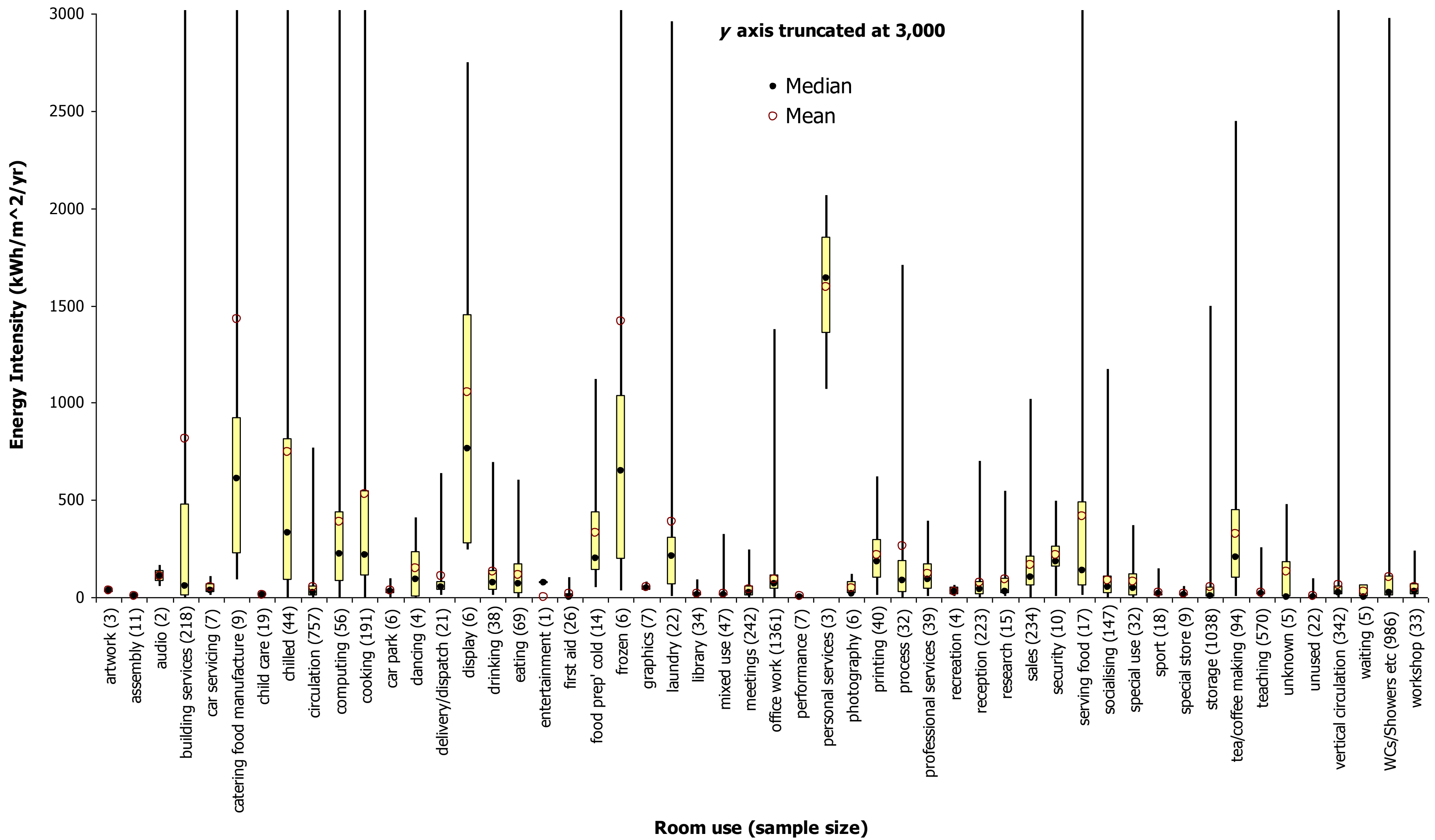

Figure 3.26: Distribution of Energy Intensities per Room Use, all premises.

The spread of EI values, for “office work” Rooms in each premises type is shown in Figure 3.27. This indicates that the spread of values is mostly quite limited. Removing the CG, CL and CR samples would further restrict the range of values. As these three Primary Description class samples are small, further data collection might drag these apparently high EI spaces more towards the range of values held in much larger samples.

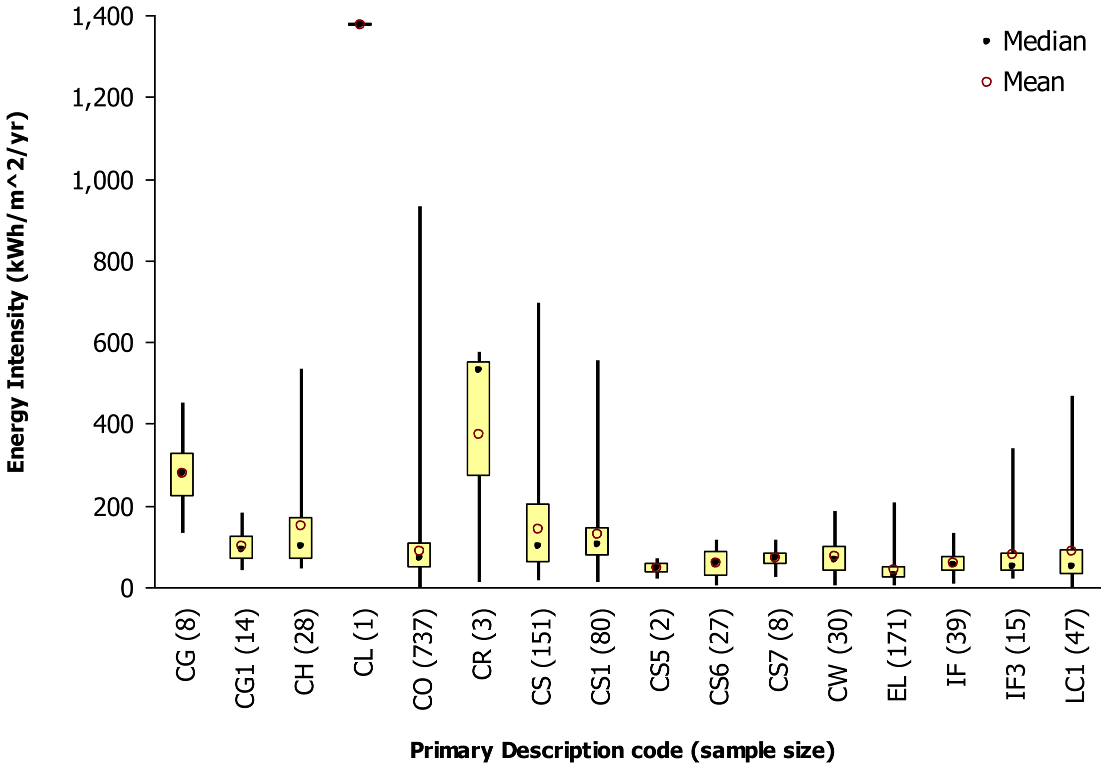

Figure 3.27: Energy Intensities of "office work" rooms in each Primary Description, in the SHU sample premises.

Although there is clearly some variation between premises types, the overall pattern suggests that “office work” is similar in its EI, across most premises types. The value of this comes later in the methodology (Section 4.7), when seeking profiles for space use and premises type combinations, for which there are no direct matches in the SHU data.

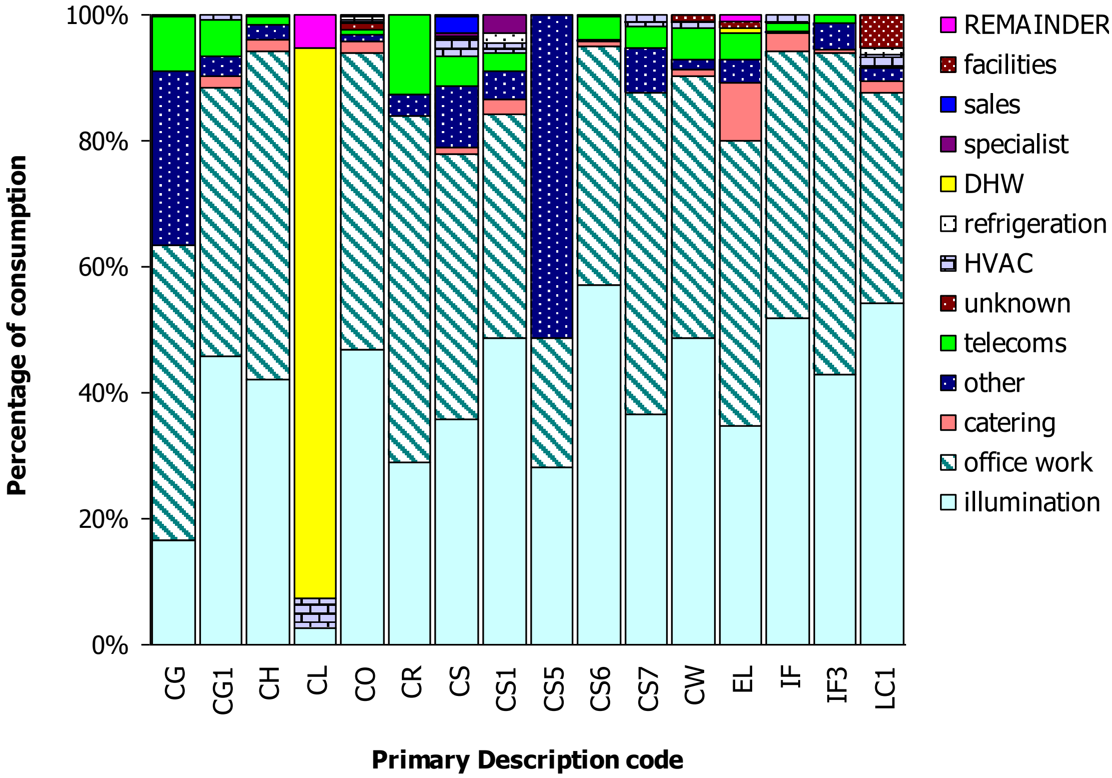

Figure 3.28: Breakdown of total consumption of all "office work" rooms, in SHU samples, per Used For group and Primary Description class.

The potential reasons for the "office work" rooms in the CG (Petrol Stations) and CL (Public Houses) Primary Description classes having visibly different electricity consumption characteristics can be investigated further in Figure 3.28, above. Here it can be seen that these premises types' office work Rooms have electricity being used for different purposes to most of the other premises types.

In the CG class, "other" uses and "telecoms" together account for 36% of the consumption, with "illumination" consumption being quite low at 16.5%. In the CL premises, the bulk of consumption is accounted for by "DHW", with "illumination" somewhat less than "HVAC" and the "REMAINDER", which contains all consumption that constitutes less than 0.1% of the total consumption of all the "office work" rooms. The other exception is class CS5 (Launderettes), which contains just two offices (both in the same premises) and one of these rooms contains a security camera and television that use 463 kWh per year between them, accounting for 25% of the consumption.

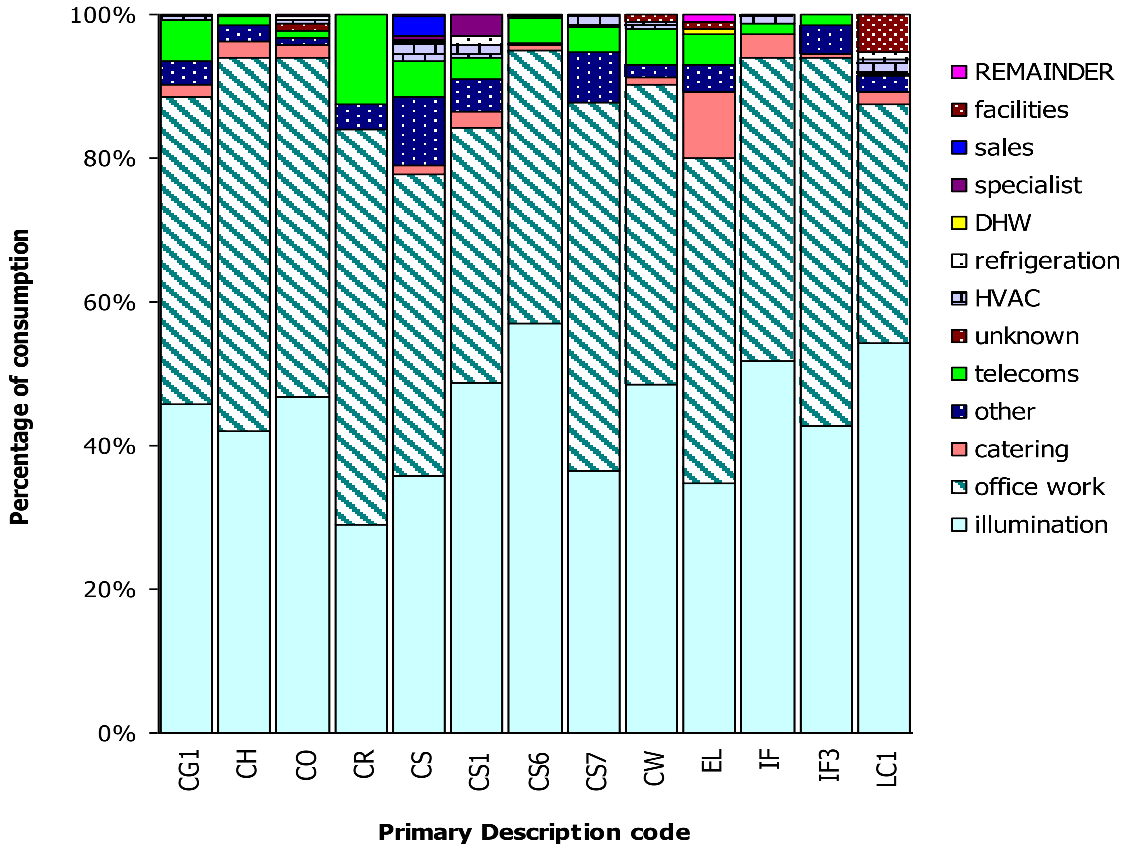

Figure 3.29: Breakdown of total consumption of all "office work" rooms, in SHU samples, per Used For group and Primary Description class, excluding CG, CL and CS5.

Figure 3.29, above, shows the profile of consumption, by Used For group, in "office work" rooms, after the Petrol Filling Station, Public House and Launderette premises have been removed. This shows patterns of consumption that are broadly similar. The updating of the population of computers may have had an homogenising effect on the profiles, through the assumption that all office rooms contain at least one computer, but if this is a reasonable assumption, the similarity of consumption per Used For group, in this subset, is valid and interesting.

Below, Figure 3.30 shows the spread of Energy Intensities for "storage" rooms in the SHU samples. Again, the spread of EIs is fairly compact, with only Restaurant premises (CR) having much spread across the middle two quartiles; however, some of the mean values lie above the third quartile. Despite this, only the Shops' (CS) storage space is likely to have much effect on models using VOA Line Entry data, as Petrol Filling Stations (CG), Hotels (CH) and Schools (EL) do not have much recorded floorspace in the VOA datasets, if any. Improved sample sizes would most likely result in an increasingly representative mean EI.

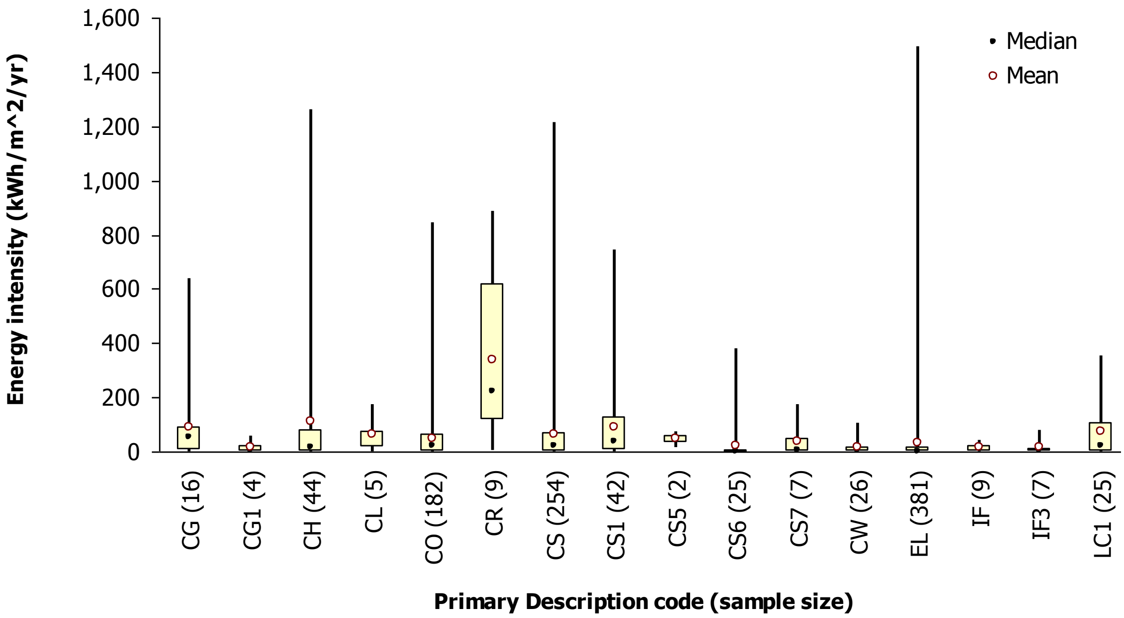

Figure 3.30: Energy Intensities of "storage" rooms in each Primary Description, in the SHU sample premises.

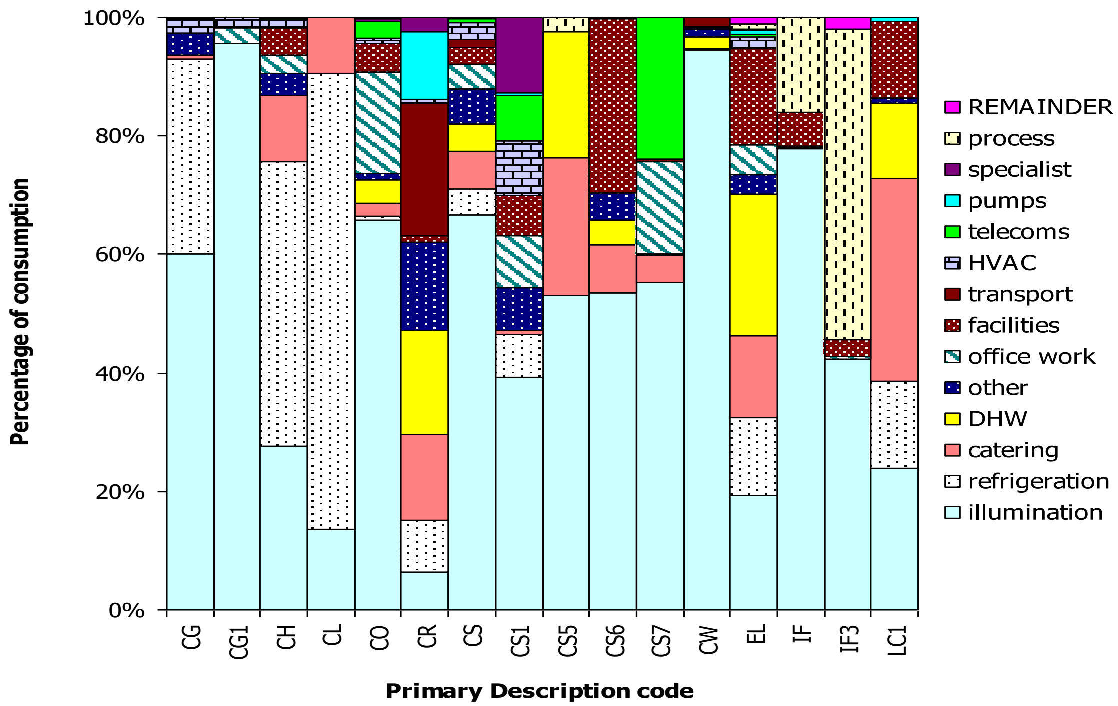

Figure 3.31: Breakdown of total consumption of all "storage" rooms, in SHU samples, per Used For group and Primary Description class.

The profile of Used For group consumption, in storage rooms, is shown in Figure 3.31, above. Considering most of the data points summarised in Figure 3.30 are below 100kWh/m^2/yr, the diversity in what the appliance consumption is Used For, is very noticeable. It may also be seen that there are appliances in the storage spaces that might not ordinarily be associated with the activity of storage. For example, in Factory (IF) storage rooms there are appliances that are being Used For "process"; whilst, in Launderettes (CS5), quite a lot of "catering" is taking place.

What appliance electricity is Used For, aggregated across all Room Uses regardless of premises type, cannot be deduced from the SHU data usefully, as the result will be unacceptably influenced by the dominance of certain premises types – namely Shops, Offices and Schools – due to their larger Room sample sizes. The number of appliances of any Used For group and the consumption per group would be dependent upon both the number of Rooms and the total area of the aggregated Room Uses. Only if the profile of all the premises were representative of the stock, would the result be valid. As the SHU data do not contain all variants of premises found in the stock, this is not the case.

3.12 Summary of Chapter 3

Chapter 3 has shown how the base SHU data are filtered and rationalised to provide profiles of space use, Energy Intensity, End Uses and Used For groups. The degree of filtering greatly reduced the number of premises that could be used in the analyses of space use and electricity consumption. For some Primary Description classes, the sample size is statistically insecure, but analysis at the individual room level, increases the sample sizes, thereby improving their robustness to some degree. Overall, it must be highlighted that these samples and their data are the only ones accessible for the progress of the methodology.

A key finding is that there is considerable variation in the types of Room Uses that occur in premises of the same Primary Description class. By analysing Valuation Office Agency (VOA) datasets of the non-domestic stock, it is possible to account for this variation in the proportions of premises that contain different activities, rather than homogenising premises into a single representation of the premises type (Primary

Description). Through this, it becomes possible to infer Energy Intensity, End Uses, Used For groups and even appliance types, in VOA datasets, with greater spatial precision than has been available, previously.

The analyses of space use and Energy Intensity also suggest that increasing premises sample sizes tends to increase the variability in the proportions of space used for core activities, whilst also reducing the degree of variability in Energy Intensities. With, in most cases such small premises sample sizes, this research is not able to provide highly robust evidence of these relationships, so the gathering of more data would be beneficial for further exploration of this hypothesis. Should such a relationship be found to be the norm, the modelling of electricity consumption in the building stock, using VOA SMV Line Entry data, could prove to be more accurate than modelling at the premises level, due to the modelling methodology being based upon the SHU Room Use Energy Intensities being mapped onto the subdivisions of premises.

The End Uses of appliances, and thus the End Uses of electricity, have also been analysed to provide profiles of End Uses in Room Uses, per premises type. Additionally, an analysis of the Used For codes, attached to appliance records, has been carried out to identify the activities for which appliances are being used in Room Use categories. Some useful advantages of using the Used For codes have been identified, compared to analysis according to End Uses, particularly in subdividing the "catering" End Use into the Used For group classes of "catering" and "refrigeration".

Generic values, derived from all instances of a Room Use have also been generated, for each of the above analyses, together with generic profiles for whole premises classes. The outputs of each of these analyses are thus made available for use in calculating an estimate of the appliance electricity consumption and consequential internal gains in non-domestic stock premises.

Chapter 4: Inferring Energy Characteristics of Non-domestic Premises in Leicester

The first part of this chapter describes data collected by the Valuation Office Agency (VOA) in its role as the body appointed by the UK government to place a taxable value on premises in England and Wales. The chapter goes on to describe which data and how they are used, as the source of a number of the primary inputs for the estimation of appliance electricity consumption and internal gains, in the test urban area, in this research.

Much of the description of the VOA data, specific to Leicester City, is contained within the description of the methodology, Sections *4.5 Leicester City VOA Data: Description and Initial Preparation* and *4.6 Rationalisation of the Leicester City Data*, below. The methods of cleaning, filtering and rationalising the test urban area data are fundamentally simple, but also have some subtleties that will be explained in detail.

The second part of the chapter deals with the method used to apply the outputs of the analyses of the SHU data, to the test urban area data.

4.1 The Valuation Office Agency as a Source of Energy Modelling Data

In view of the financial nature of the VOA's role, it is assumed that its data are reasonably reliable. If the data were to cause an over-valuation of real estate, the persons responsible for paying the taxation are likely to complain and seek corrections. But the government will try to ensure that it does not allow any under-valuing of premises, so that it may maximise revenue.

To ensure consistency in how premises are valued, the VOA uses a classification system based on the principal activity occurring within the premises (ODPM, 2006).

4.2 Classification of Premises

At the highest level of categorisation, the VOA classifies non-domestic premises into one of four Bulk Classes, based upon their overall activity:

- Retail
- Offices
- Factories
- Warehouses

In 2008, the four Bulk Classes accounted for 1.365 million premises of the total 1.795 million premises, in England and Wales (DCLG, 2010c).

In addition to these Bulk Classes, there are classifications for "Land", "Miscellaneous" and "Non-bulk" premises (ODPM, 2006). These categories include some major users of energy, such as health buildings, educational establishments, leisure facilities and hotels.

The next layer of classification is the Primary Description of the premises' activity, which is allocated a Primary Description code (PD code). The PD code is formed of two letters, for example "CS" is the code for "Commercial Shop" and "IF" is the code for "Industrial Factory". Further refinements are achieved by adding digits to the code, so the PD code for "Bank or Agency" is "CS1"; the code for "Showroom" is "CS7"; and the code for a "Workshop" is IF3. In total, there are 106 PD codes.

In addition to the PD codes, the VOA will also classify premises according to a Special Category code (SCAT code), of which there are 448 describing the activities performed in premises. The codes take the form of 3 digits and one letter and give a greater level of detail than the PD code. However, the SCAT code is applied before the PD code (Burdon, 2010), so the PD code is a simplification of the SCAT.

Domestic premises that contain areas used for business purposes – for example, a small workshop, or a sole trader bookkeeper's office within a house – are termed "composite" premises. These premises have Business Rates charged on the area devoted to business activity. Within a large, densely-populated area, there may be many such small subdivisions of domestic buildings. This adds a potential complication to the calculation of energy consumption for non-domestic premises, due to thermal boundaries, service systems and energy meters shared with domestic activities, as indicated in Section 2.1.5, above.

4.3 Collection of Data, Using Valuation Surveys

Standardised valuation survey methods are used, to collect the data required for valuations. These surveys consider factors such as floor area, access, geographical location, premises activity, presence of air conditioning and suchlike and how these affect the value of the property. Although not designed with energy surveys in mind, some valuable information can be extracted from the VOA data, for use in energy consumption modelling.

The overall methodologies vary, according to the premises' principal activity classification; for example, public houses are valued according to their estimated trading turnover (Valuation Office Agency, 2010a), but most premises types are valued according to floor area. Within the classes valued by floor area, there is also some variation in the convention used for the measurement of rateable areas.

The areas of premises are measured, by the VOA, using one of two conventions. Net Internal Area (NIA) is used primarily to value premises in the Offices and Retail Bulk Classes, whilst Gross Internal Area (GIA) is used to measure premises in the Factory and Warehouse Bulk Classes (ODPM, 2006).

Table 4.1, below, summarises these measurement conventions for the VOA Bulk Classes and the other categories of premises.

Table 4.1: Summary of application of VOA area measurement conventions.

		Measurement convention	
Bulk Class	**Premises type**	**GIA**	**NIA**
Retail			●
Offices			●
Factories		●	
Warehouses		●	
Other bulk premises:	Garden Centres		●
	Clubs and Institutes		●
	Day Nurseries and Play Groups		●
	Community and Day Care Centres	●	
	Club Houses	●	
	Village Halls	●	

NIA is used where it is important to define useful space; that is, space that can actually be used for the activity listed in the SMV and this space is considered to be a major determinant of the earning potential of the premises. For this reason, areas occupied by cleaners' cupboards, staff toilets, structural support columns, staircases and such like, are not included in the measurement, as these are not used as office space or sales and support areas. However, the existence of these non-valuable areas may be recorded in the SMV.

GIA essentially measures all of the area within the internal face of the exterior walls.

A summary of the inclusions and exclusions of the two measurement conventions is shown in Table 4.2, below (ODPM, 2006).

Table 4.2: Summary of VOA Code of Measuring Practice Definitions for Rating Purposes.

GROSS INTERNAL AREA (GIA)		**NET INTERNAL AREA (NIA)**
Broadly Speaking: The whole enclosed area of a building within the external walls taking each floor into account and excluding the thickness of the external walls		Broadly speaking: The usable area within a building measured to the face of the internal finish of perimeter or party walls ignoring skirting boards and taking each floor into account
GIA will include		**NIA will include**
1. Areas occupied by internal walls (whether structural or not) and partitions		1. Perimeter skirting, moulding, or trunking
2. Service accommodation such as WCs, showers, changing rooms and the like		2. Kitchens
3. Columns, piers, whether free standing or projecting inwards from an external wall, chimney breasts, lift wells, stairwells etc		3. Any built in units or cupboards occupying useable areas (subject to height exclusion below)
4. Lift rooms, plant rooms, tank rooms, fuel stores, whether or not above roof level		4. Partition walls or similar dividing elements
5. Open-sided covered areas (should be stated separately)		5. Open circulation areas and entrance halls, corridors and atria (but see 9 and 10 below)
GIA will exclude		**NIA will exclude**
6. Open balconies		6. Toilets and associated lobbies (but extra measurements may be required for shops where they are either in excess of normal staff requirements considering the type and size of shop) or it is apparent additional toilets have been installed)
7. Open fire escapes		7. Cleaners' cupboards
8. Open-sided covered ways		8. Lift rooms, boiler rooms, tank rooms, fuel stores and plant rooms other than those of a trade process nature
9. Open vehicle parking areas, terraces and the like		9. Stairwells, lift wells, those parts of entrance halls, atria, landings and balconies used in common or for the purpose of essential access
10. Minor canopies		10. Corridors and other circulation areas where used in common with other occupiers or of a permanent essential nature
11. Any area with ceiling height of less than 1·5m (except under stairways)		11. Areas under the control of service or other external authorities
12. Any area under the control of service or other external authorities		12. Internal structural walls, walls (whether structural or not) enclosing excluded areas, columns, piers, chimney breasts, other projections, vertical ducts etc
NOTE: The areas of items 6 to 11, although excluded from GIA, should be calculated and shown separately.		13. The space occupied by permanent air conditioning, heating or cooling apparatus and ducting which renders the space substantially unusable having regard to the purpose for which it is intended
		14. Areas with headroom of less than 1·5m (this area should be shown separately but excluded)
		15. Car parking areas (this area should be shown separately and the number of spaces noted)

The VOA uses the information gathered during the valuation process to maintain two key databases of information: the Rating List database and the Summary Valuation database, with the latter appearing to inform parts of the former.

4.4 Structure and Content of VOA Datasets

The principal sources of data, used in non-domestic stock modelling, are the Rating List and the Summary Valuation datasets. This section describes these two datasets and highlights the data used for this research's methodology.

4.4.1 The Rating List

The Rating List is the most important source of information from the VOA as it contains a dataset for the majority of premises in England and Wales. Noteworthy exceptions are some properties owned by the Crown (e.g. Ministry of Defence Estates), places of worship and agricultural buildings and agricultural land.

Each premises' dataset includes information useful for stock energy modelling. For this research, the most useful elements of the Rating List are:

- The Billing Authority Reference: a unique premises identifier
- A Primary Description code (PD code)
- Primary Description: a textual description of activity
- The premises' rateable value, in Pounds Sterling
- Postal address
- Post code
- The local authority responsible for the collection of Business Rates

Note that the Rating List does not contain the floor area of premises. There are also some hereditaments that do not have any floor areas, such as advertising rights (Primary Description code CA).

4.4.2 The Summary Valuation Database

The Summary Valuation database (SMV) contains data about the four Bulk Classes. These are essentially the same data types as the Rating List (except for the PD code), but with additional information that is extremely significant when modelling building stock energy consumption. Each entry for premises in the SMV is called a Line Entry.

There may be more than one Line Entry per premises, each of which describes a definable area, or noteworthy (in valuation terms) characteristic of the premises.

In order of importance to this research, the most relevant pieces of information recorded in Line Entries are:

- Billing Authority Reference – this links each premises to its Rating List dataset
- Total area, in m^2, for each premises
- Property Description
- Line Entry number: 1, 2, 3 and so forth
- Line Description: a textual description of the activity carried out in the Line Entry
- Area, in m^2, of the Line Entry – sometimes this is recorded as "0", due to the space use of the Line Entry not requiring a taxation value; e.g. Staff toilets
- Floor of the building on which the Line Entry occurs: basement, ground, 1, 2 and so forth

Each premises' SMV dataset is made up of at least one Line Entry. Some premises will have a single Line Entry, whilst others may have several. Figure 4.1, below, shows the distribution of the number of Line Entries per premises, for the City of Leicester; this demonstrates that the majority of these premises have more than one Line Entry. The figure does not match the findings of Bruhns (2000, page 39), which indicated a typical number of line entries per premises as "four or five", for the UK stock as a whole.

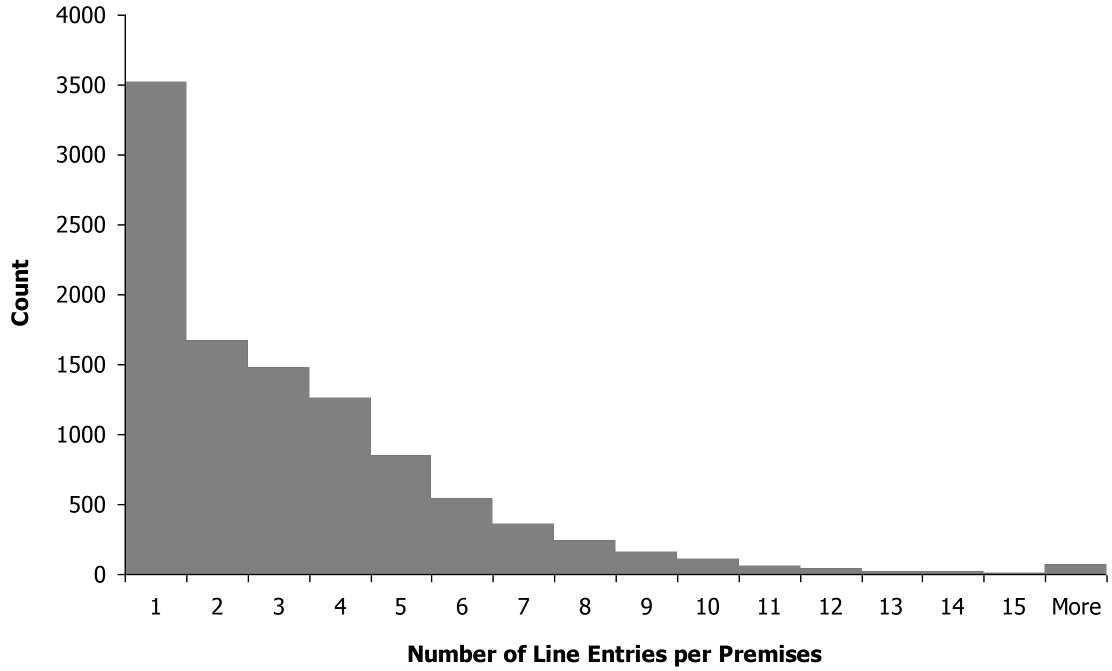

Figure 4.1: Frequency of number of Line Entries per premises in Leicester City (Source: VOA 2009)

Table 4.3 (following page), shows information that can be gathered from the Rating List and/or the SMV, together with field names and unit of measurement, within each database.

Table 4.3: Premises' accessible information and sources within VOA databases.

Rating List		**Summary Valuation data (SMV)**		**Information provided**	**Unit of measurement**
Data name	**Field name**	**Data name**	**Field name**		
Billing Authority Reference	BA Ref	Billing Authority Reference	BARefNo	Unique identifier for each premises	n/a
Primary Description Code	PDCode	-	-	A code for the description of the principal activity within the premises	code
Primary Description	Description	Property Description	PropertyDescription	A text description of the principal activity of the premises	descriptive text
-	-	Total Area	TotalArea	Total taxable area of the premises	m^2
-	-	Line Entry	Line	The number of subdivisions of each premises (Line Entries)	number
-	-	Line Description	LineDesc	Textual description of the activity carried out in the area of the Line Entry	descriptive text
-	-	Area of Line Entry	Area	Area of the Line Entry (where recorded)	m^2
-	-	Floor	Floor	Floor of the building on which the Line Entry occurs	basement, ground, 1, 2 and so forth
-	-	Other Adjustments	OA Desc	Additional information about items that affect taxable value, such as the known existence of air conditioning or mezzanine floors, and the area (m^2) of the premises affected by this.	descriptive text
-	-	Other Adjustments’ area	OASize	Total area affected by the Other Adjustments in the premises (may be spread across more than one Line Entry)	m^2
Postal Address	Property Address	Postal Address	NameNumberProperty	The postal address of the premises	text
-	-	Postal Address	Street	The postal address of the premises	text
Post Code	Postcode	Post Code	Postcode	Post Code for premises	code
Special Category Code	ScatCode	-	-	A classification of the premises’ economic activity sector	code
Rateable Value	AdoptRV	Rateable Value	AdopRV	The rateable (taxable) value of the whole premises	£

From across the Rating List and the SMV, it is possible to gather the following information, of primary significance:

- Premises unique identifier
- The premises' activity Primary Description and its code
- The total rateable area (m^2) of the premises
- The number of area subdivisions of each premises
- A description of space use within area subdivisions of each premises
- The measured area (m^2) of space use subdivisions
- Rateable value (£) of the premises
- Post Code of the premises

Information that, for this research is of less direct significance, and has remained unused, but is still generally important for stock energy modelling, is:

- Postal address of the premises
- The floor(s) on which any subdivisions of premises area occur
- Other Adjustments – additional information influencing the rateable value and the area (m^2) affected
- The Special Category Code for the premises

The VOA databases are extremely informative about the non-domestic stock, but some of the valuation methodologies result in a lack of certain data types for some premises types.

The first problem is that not all premises that appear in the Rating List appear in the SMV. For example, public houses are valued according to their estimated trading turnover (Valuation Office Agency, 2010a), so public houses do not generally appear in the SMV, though there are occasional exceptions. Other premises types that appear in the Rating List, but generally not in the SMV, are schools, health buildings and public recreation premises and suchlike. Where these premises do not appear in the SMV, they have no record for their floor area and there can be no breakdown of their internal space use.

4.4.2.1 Property Descriptions

The Property Description, recorded in the SMV, is equivalent to the Primary Description held in the Rating List and Local Land and Property Gazetteer (see Section 2.2.6).

4.4.2.2 Line Descriptions

The Line Entries of the SMV contain a field named "LineDesc" – a shortening of Line Description. This Line Description field is used to record information about the use of the floor area described in that Line Entry.

4.4.2.3 Accommodation Use Codes

The VOA uses a system of Accommodation Use Codes (AUCs) that are applied to spaces within premises. The VOA data used in this research are from 2008, so are assumed to have been compiled using the Valuations Scales for the 2005 revaluation. There are 79 Valuation Scales, which prescribe the codes that can be applied to Line Entries in particular premises types, so only certain codes should appear in certain premises.

There are 105 AUC descriptions, in all, and these appear in the Line Description field of Line Entries in the SMV database. Sixty-six of these descriptions are relevant to internal spaces of premises, and are shown in Table 4.4, below.

Table 4.4: Accommodation Use Codes – Internal and/or External.

AUC Description	Internal	External	AUC Description	Internal	External
All main areas	●		Locker room	●	
Amusement Arcade	●		Lounge	●	
Ancillary Office	●		Lower Ground Floor sales	●	
Atrium	●		Mess/Staff room	●	
Banking Hall	●		Nursery	●	
Bar	●		Office	●	
Boardroom	●		Other Retail Zone	●	
Canopy	●	●	Plant room	●	
Canteen	●		Portable Building	●	
Cells	●		Production Area	●	
Changing room	●		Public toilets	●	
Chill store	●		Reception / Entrance	●	
Classroom	●		Remaining Retail Zone	●	
Cold store	●		Restaurant	●	
Committee Room	●		Retail Area	●	
Computer room	●		Retail Zone A	●	
Covered Area	●	●	Retail Zone B	●	
Filling Station shop	●		Retail Zone C	●	
First floor production area	●		Retail Zone D	●	
First floor sales	●		Retail Zone E	●	
Food Processing Area	●		Retail Zone F	●	
Function Room	●		Sales Display area	●	●
Garage	●	●	Shed	●	●
Gatehouse	●		Showers	●	
Glasshouse	●	●	Showroom	●	
Ground Floor Sales	●		Staff toilets	●	
Health Centre	●		Storage	●	
Hi Tech Accommodation	●		Store	●	
Internal storage	●		Strongroom	●	
Kitchen	●		Surgery	●	
Laboratory	●		Warehouse	●	
Lift Shaft	●		Works office	●	
Loading Bay	●	●	Workshop	●	
Lock Up Garage	●	●			

Source: (Valuation Office Agency, 2010b)

In addition to the descriptions of internal spaces, there are other descriptions which refer to what are assumed, for this research, to be external spaces. There are also a few descriptions that cannot be reliably defined as internal or external spaces, or spaces that contain appliances. However some of these ambiguous spaces such as "Covered Area" are intended to describe some parts of garden centres and car showrooms, so it is probable (but not certain) that they are unlikely to constitute walled buildings. On the other hand, a "Lock Up Garage" constitutes a building, but is unlikely (but again not certain) to contain appliances.

A number of descriptions for other items – mostly advertising rights – do not constitute internal spaces with a significant bearing on the electricity consumption of the stock. All of these AUC Line Descriptions of non-internal spaces are given in Table 4.5, below, which shows the AUCs for:

- Parts that, for this research, are assumed to be "External" to the building envelope of premises
- "Other" rateable parts of premises that do not necessarily form internal areas within premises
- "Unknown" are such that the description does not indicate whether the space is internal or external to the building envelope of premises

Table 4.5: Accommodation Use Codes - External, Other & Unknown.

AUC Description	External	Other	Unknown	AUC Description	External	Other	Unknown
12 Sheet(s) Advertising Display		•		Disabled Parking Space(s)	•		
144 Sheet(s) Advertising Display		•		Double Demy Advertising Display		•	
16 Sheet(s) Advertising Display		•		Double Royal Advertising Display		•	
192 Sheet(s) Advertising Display		•		External storage	•		
32 Sheet(s) Advertising Display		•		Hard Surfaced, fenced land	•		
4 Sheet(s) Advertising Display		•		Hard Surfaced, unfenced land	•		
48 Sheet(s) Advertising Display		•		Lorry/Truck Parking Space(s)	•		
6 Sheet(s) Advertising Display		•		Misc Area			•
64 Sheet(s) Advertising Display		•		Motorbike Parking Space(s)	•		
8 Sheet(s) Advertising Display		•		Number of Beach Huts		•	
96 Sheet(s) Advertising Display		•		Outdoor display/seating area	•		
Abattoir Lairage			•	Parking Area	•		
Advertising Display		•		Parking Space(s)	•		
Area (m^2) of Advertising Display		•		Quad Demy Advertising Display		•	
Area of Beach hut(s)		•		Rough surfaced, fenced land	•		
Bicycle Parking Space(s)	•			Rough surfaced, unfenced land	•		
Coach Parking Space(s)	•			Unclassified area			•
Crown Double Advertising Display		•		Unsurfaced, fenced land	•		
Crown Quad Advertising Display		•		Unsurfaced, unfenced land	•		

Source: (Valuation Office Agency, 2010b)

The AUC description "Office" has three codes: "OFF", "OFO" and "ANO"; the last of these codes can also denote "Ancillary Office". The code "ASO" has two descriptions: "Storage" and "External Storage". In the database, used in this research, the AUC codes do not appear but the descriptions do appear, so the descriptions have been used. Also, only some Line Entries have the designated AUC descriptions, but there is a considerable number of Line Descriptions, within the Leicester SMV, that do not perfectly match the AUC descriptions. These types of Line Description are described more fully in Section 4.6.3.

4.4.2.4 Adjustments

In addition to the Line Description, some Line Entries also include what are termed "adjustments" to the rateable value of the space described in the Line Entry. Such adjustments include a description of the basis of the adjustment, for example, the existence and floor area treated by air conditioning. Sometimes, vehicle parking spaces are recorded in the adjustments field, but where this is the case, it appears that their areas are not recorded, implying that each parking space has a standard area.

In the Leicester SMV there are a total of 970 premises with adjustments. There is a total of 187 different types of adjustment. There are 209 premises with adjustments for air conditioning, whilst the bulk of other adjustments refer to external areas. Although the existence of air conditioning has an effect on premises energy consumption, the apparently low level of its existence in Leicester seems unreasonably low. Also, the overwhelming majority of adjustments, in the Leicester data, have little or no bearing upon appliances, so a full listing and analysis of adjustments have not been included in this research.

4.5 Leicester City VOA Data: Description and Initial Preparation

Although Section 2.2.5 describes what might be called the standard approach to premises taxation data, taken by the VOA, the reality of the databases provided for this research is slightly different and warrants some further description. Reference to Table 4.3, on page 110, explains the relationships between the various database fields referred to below. Reference to Figure 4.2, below, is also recommended.

To aid explanation of how the VOA data were prepared, prior to the inference of appliance electricity consumption and consequent internal gains, a schematic is included (Figure 4.2), below. It may be useful to refer back to this figure when reading Sections 4.5 and 4.6.

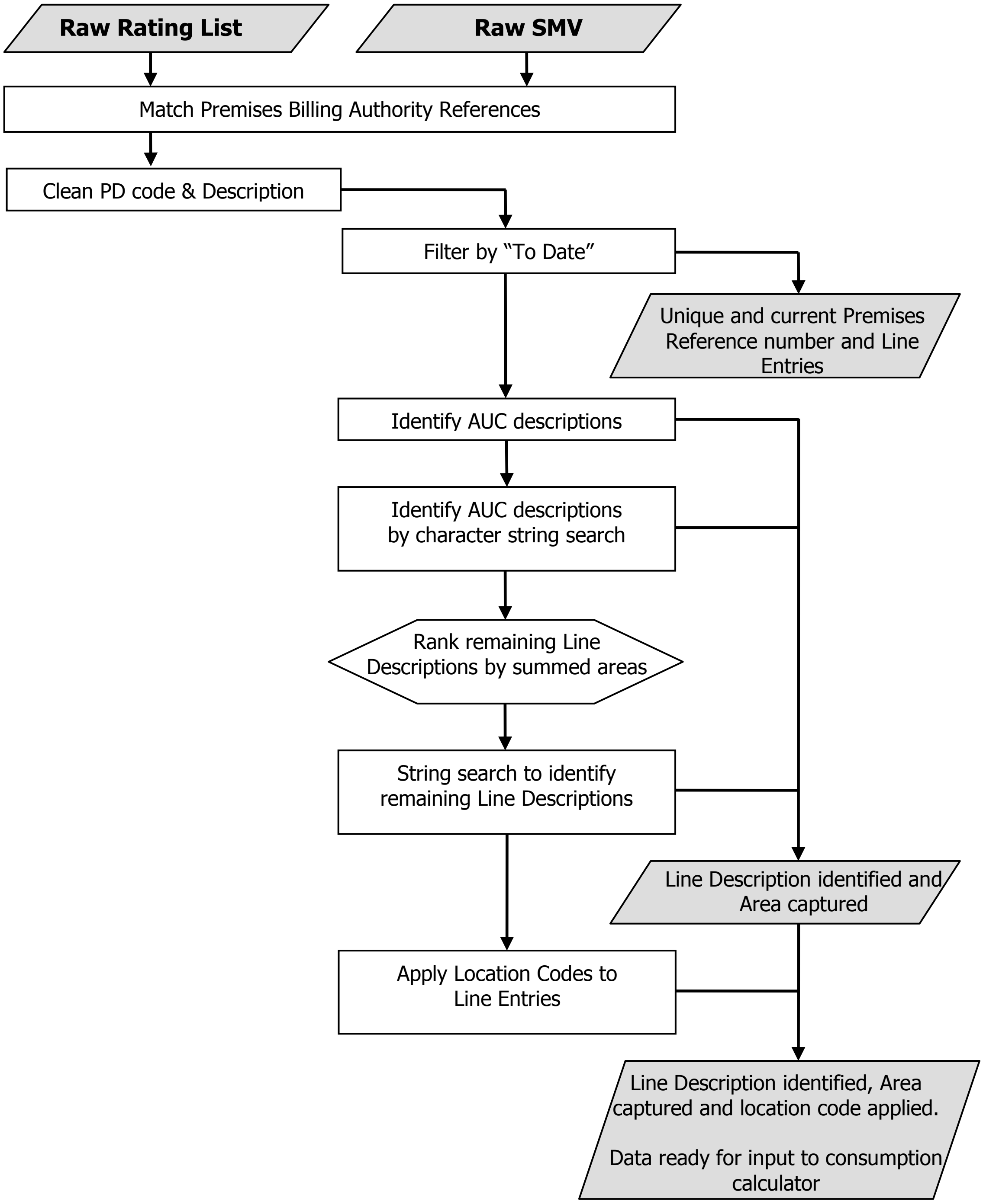

Figure 4.2: Flowchart of preparation of Leicester City VOA data.

The 2008 Rating List (RL) provided for the Leicester City Council Billing Authority Area contains 11,636 unique records, or premises. As supplied, the equivalent Summary Valuation database (SMV), for Leicester City, has 54,582 Line Entries. Further investigation revealed that within the SMV there were 12,199 unique premises. Having more premises in the SMV, than in the RL does not accord with the VOA methodology, as not all premises types that appear in the RL are recorded in the SMV, therefore the number of premises in the SMV should logically be fewer than in the RL. The explanation for this situation was found in the SMV, where some premises had multiple entries.

In most cases, these extra entries were historical, i.e. non-current, records for premises. However, in a number of cases, it was found that some premises had been allocated more than one unique Billing Authority Reference (BARefNo) in the SMV. Detailed inspection of the datasets indicated that the actual number of unique Line Entries and hence unique premises could be extracted using the contents of each record's "To Date" field. Where the contents of the field was ".", this denoted the current record – presumably because the "To Date" was open-ended and therefore still applicable. Cross-referencing the RL BA Ref with the SMV BARefNo, for each premises, highlighted the currently applicable premises identifier. This cross-reference filtering process concluded that there were 10,377 unique and current premises in the SMV.

4.6 Rationalisation of the Leicester City Data

Initial interrogation of the datasets provided for Leicester City premises quickly indicated that there were a number of discrepancies and apparent anomalies both between the data tables and within the data tables. As a consequence, some data cleaning was required to ensure consistency across the data, where this could be achieved.

4.6.1 Cleaning the Premises' Primary Descriptions and Codes

The VOA uses 107 Primary Description (PD) codes and 77 of these appear in the Leicester City VOA Rating List. Within the Leicester City Rating List there are also 22 PD codes that are non-standard codes. A small number of these non-standard codes appear to be typos, whilst the majority appear to be intended to impart additional information about the primary activity in the premises; for example, the PD code

"CSW" has the description "SHOP,WORKSHOP AND PREMISES", in the Rating List. Due to these extra non-standard PD codes and the variety of Primary Descriptions used in its Rating List, there are 521 combinations of PD code and Primary Description in the Leicester City Rating List, equating to an average of one combination per 23 premises.

To reduce the degree of variability in the matching of Primary Description and PD code, the strings "_and_premises" and "_&_premises" were removed from the Description field (where _ represents a blank space in the record)*. The VOA indicates that the existence of the word "premises" makes "no difference" to the premises classification (Burdon, 2010). Also, "Offices" was shortened to "Office" and "Workshops" to "Workshop". The above modifications reduced the combinations of PD code and Primary Description to 431, within the Rating List. Table 4.6, below, shows the filtered PD codes and their descriptions, which have been rationalised.

Table 4.6: Filtered Primary Description codes and descriptions, for Leicester.

PD Code	Description	PD Code	Description
CG1	Vehicle Repair Workshops & Garages	CW1	Land Used For Storage
CG2	Bus Garage	CW2	Storage Depots
CG3	Garage	CW3	Stores Within/Part of Specialist Property
CL1	Wine Bar	CX	Various Commercial
CL2	Clubs & Institutions	EN1	Nursery
CO	Office	EP	Public and Independent Schools
CP	Car Park	EX	Various Educational
CP1	Car Park Space	IF	Factory
CR	Restaurant	IF2	Works
CR1	Café	IF3	Workshop
CS	Shop	IX	Various Industrial
CS1	Bank	LC	Community Day Centres
CS10	Retail Warehouses and Foodstores	LC1	Clubhouses
CS2	Betting Offices	LC3	Public Halls
CS3	Hairdressing/Beauty Salons	LT1	Amusement Arcades
CS4	Kiosks Within/Part of Specialist Property	LX	Various Leisure
CS5	Launderette	MH	Surgery
CS6	Post Offices	MH1	Health Centre
CS7	Showrooms	ML	Offices Within/Part of Specialist Property
CS9	Large Shop	MX	Various (mostly) Municipal
CW	Warehouse		

For future reference, this table can also be found in Appendix F on page 216.

* A small number of premises had the description "Premises" only and these were not changed.

There are also discrepancies in the descriptions of premises' primary activities between the three database tables of Leicester City premises, i.e. the Rating List, the SMV and the LLPG. Linking all three tables gives 324 combinations of PD code, Rating List Description, SMV Property Description and LLPG Use (based upon the 431 combinations, above), due to some premises types not appearing in the SMV and/or LLPG. When the joined tables were further filtered by the Rating List's PD code and Primary Description, the number of combinations was limited to 274. This means that for Leicester City there are 274 combinations of PD code and Primary Description, within the Rating List, that can be applied to Line Entries within the SMV.

Further investigation of the combined data tables revealed how the activity description differed between the Rating List and/or the SMV and/or the LLPG. Table 4.7, below, gives a summary of the nature and numbers of discrepancies between the Rating List's PD codes and the various premises activity descriptions in the SMV and the LLPG. There were a number of combinations of the various faults in the data, so the total number of premises with non-standard datasets (excluding typos) is 380, or 4.25% of the 9,051 premises identified in all three databases.

To make the output of this research applicable to as many premises as possible, it was decided to apply the method only to the unique and current premises in the combined Rating List and SMV. Filtering the premises by the LLPG would reduce the number of premises to which the method could be applied.

Table 4.7: Discrepancies between PD codes and descriptions in Leicester City data.

Nature of discrepancy *	Count of premises
Non-standard PD code	51
Non-standard premises description	126
Discrepancy between PD Code and Rating List "Description"	247
Discrepancy between PD Code and SMV "Property Description"	247
Discrepancy between PD Code and LLPG "Use"	278

*Note that PD *codes* are only held in the Rating List

Of the 87 premises that had some form of mismatch of overall activity descriptions, between one or more of the tables, 71 had Line Descriptions that were relevant to the PD code (though these codes were sometimes non-standard). This suggests that Line Descriptions tally quite well with PD codes, even where the Primary Description does not. As PD codes only appear in the Rating List, any process that required the alignment of Primary Descriptions and Line Entries was based upon the records of PD codes, held in the Rating List. From this combination, the relationship between overall premises activity and the activities described in Line Entries may be studied.

Further examination indicated that overall there are many divergences from how the Special Category (Scat) codes, Primary Description codes, Primary Descriptions and Line Entries ought to be applied, according to the VOA methodology. In summary, the data have errors. However, as this research focussed upon Line Entries, it was decided to use the Line Description as the primary descriptor of space usage, followed by the PD code. This method was used because the weight of evidence of activity descriptions is balanced in favour of Line Descriptions over PD codes and Primary Descriptions.

Finally, to align the PD codes to the standard types listed by the VOA, all codes were shorn of their additional non-standard characters. For example, the PD code "CSW", with the Primary Description of "SHOP,WORKSHOP AND PREMISES", was truncated to "CS". This process reduced the number of PD Codes in the joined Leicester Rating List and SMV to 42 codes. After removing PD code "CA" Advertising Rights premises, which have no floorspace, the final number of codes was 41.

4.6.2 Discrepancies in Area Records

A number of anomalies were found in the records for rateable areas, within the Leicester City SMV. These consisted of differences between the sum of the areas recorded in Line Entries and the Total Area recorded for the premises. There were 405 instances where this occurred, equivalent to 4% of the total number of premises (excluding PD Code CA, Advertising Rights). In all 405 cases, the sum of the Line Entry Areas was less than the Total Area of the premises. The sum of the differences accounted for only 0.26% of the sum of Total Areas in the SMV. Figure 4.3, below, shows the count of premises and the size of the discrepancies between their Total Area and the sum of their Line Areas, expressed as a percentage.

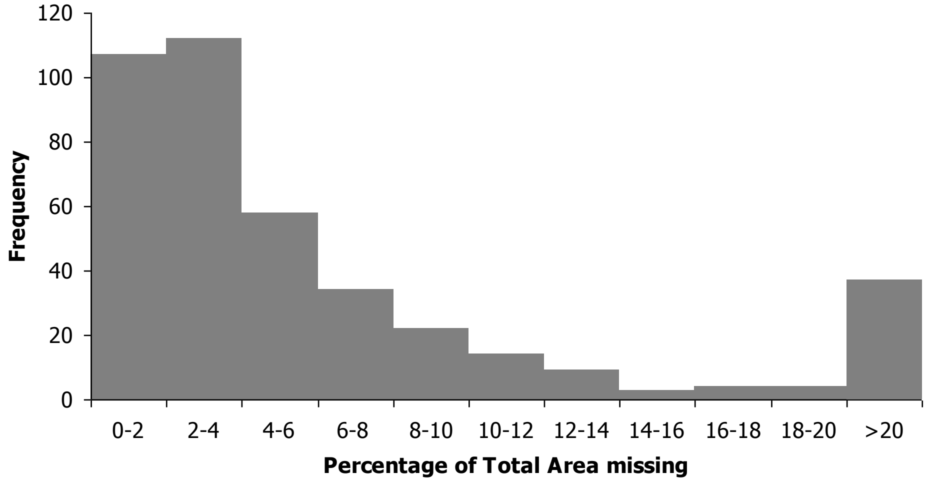

Figure 4.3: Frequency of percentage discrepancy in sum of Line Entry areas, as a percentage of premises' Total Area

In Figure 4.3, it can be seen that the discrepancies are generally small, but a few of the records in the category ">20" are very high, with a maximum of 69% for one premises. This single premises record accounts for 31% of the sum of all the differences, in the SMV.

Visual inspection of the data suggests that the differences might be attributable to areas within premises that are not taxable, for example Staff Toilets and Plant Rooms. This observation does fit with the low percentage errors, but not with those over 20%. However, more than 50% of the premises in the >20% error band have "Internal Storage" (or similar) without recorded areas. It seems possible that these Line Entries have changed, from a taxable use, to the sometimes non-taxable use "Internal Storage", or similar, and the Total Area has not been updated. This appears to be unimportant in terms of the Rateable Value (which is based upon each Line Entry), but it might have implications for information generated from the Total Area of premises.

Table 4.8, below, gives the discrepancy for each Primary Description, sorted by the percentage difference. From this it may be seen that some of the discrepancies lie in premises types that are not measured to the Net Internal Area convention, such as Factories (PD code IF), so all parts of the premises should be measured and the two areas should be the same.

Table 4.8: Discrepancies between premises Total Areas and Summed Line Areas, per Primary Description.

PD Code	Sum of Total Area	Sum of Line Areas	Difference	Percentage Difference
CS5	975	875	100	10.24
CR1	6219	6033	186	2.99
EN1	16375	16131	244	1.49
ML	7747	7634	113	1.46
CS2	3552	3502	50	1.41
CS1	20622	20393	230	1.11
CR	42723	42366	357	0.84
MH	24250	24105	145	0.60
CS	523091	519971	3120	0.60
CS3	6995	6963	33	0.47
CO	463123	461260	1863	0.40
IF	1372577	1368853	3723	0.27
CS7	20241	20187	55	0.27
CL2	37139	37089	50	0.14
CW2	7296	7287	9	0.12
IF3	200745	200514	231	0.11
CW3	40550	40540	10	0.02
CW	848032	847847	185	0.02
CG3	68200	68190	10	0.01
CG1	44617	44613	4	0.01

The overall discrepancy is small and has been ignored, as it represents only 0.26% of the sum of Total Area. As the use of the area of the discrepancies cannot be known reliably, this research assumes that the values held in the individual Line Entries are correct and the Total Area field is not used to describe the area of premises. This route was also chosen because the overall valuation of premises is based upon the sum of values derived from the combination of Line Description and Line Area, rather than a valuation of the Total Area of the premises.

4.6.3 Identifying and Rationalising Line Descriptions

Table 4.4 and Table 4.5, on pages 113 and 114, list the 115 descriptions attached to Accommodation Use Codes, which the VOA used in the 2005 revaluation to describe how space is used in premises, at the Line Entry level within the SMV. In the Leicester VOA datasets (excluding PD Code CA, Advertising Rights) there are 3,504 combinations of PD Code and Line Description made up of 2,552 unique Line Descriptions. A visual inspection of the data indicated that it would be possible to rationalise the 2,552 into a smaller, more practical number that would still be descriptively representative. This section describes the method for achieving a reasonable reduction in the number of Line Descriptions, whilst also retaining as much detail as possible.

Figure 4.4, below, is a representation of the first two stages of identifying the Line Description (LineDesc) recorded in the Line Entries of the SMV. The following explanation will use cell references indicated on the figure – A1, B2, C3 and so forth.

The input data for the hypothetical premises AA and BB are held in columns A, B, C and D, rows 3 to 8 and 10 to 14; these are extracted from the VOA Rating List and SMV database tables and exported to a spreadsheet. The software programmes used in this part of the research were Microsoft Access 2003 and Microsoft Excel 2003, which were deemed capable of handling and processing the volumes of data encountered. The objective of this section of the methodology is to identify the Line Description and capture its corresponding area, with the intention of maximising the total area captured, ready for the application of an Energy Intensity profile.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1					**Stage 1**									**Stage 2**								
2	**BA Ref**	**Line**	**Line Description**	**Area (m^2)**	Production Area	Office	Kitchen	Storage	Staff Toilets	Line Identified 1 = TRUE		Area Captured	Carry forward to Stage 2?	Production Area	Office	Kitchen	Storage	Staff Toilets	_yard *	Line Identified 1 = TRUE		Area Captured
3	AA	1	Production Area	1000	1					1		1000	NO							0		0
4	AA	2	Offices	100						0		0	YES		1					1		100
5	AA	3	Storage	90				1		1		90	NO							0		0
6	AA	4	Staff Toilets	0					1	1		0	NO							0		0
7	AA	5	Kitchen	20			1			1		20	NO							0		0
8	AA	6	Timber Yard	100						0		0	YES						1	1		100
9			**Total area**	**1310**		**Count of descriptions identified**				**4**	**Subtotal of areas captured**	**1110**			**Count of descriptions identified**					**2**	**Subtotal of areas captured**	**200**
10	BB	1	Production Area	1000	1					1		1000	NO							0		0
11	BB	2	Offices/Storage	190						0		0	YES		1		1			2		0
12	BB	3	Staff Toilets	0					1	1		0	NO							0		0
13	BB	4	Kitchen	20			1			1		20	NO							0		0
14	BB	5	Timber Yard	100						0		0	YES						1	1		100
15			**Total area**	**1310**		**Count of descriptions identified**				**3**	**Subtotal of areas captured**	**1020**			**Count of descriptions identified**					**1**	**Subtotal of areas captured**	**100**
16			**Sum of areas captured**																			
17	AA			**1310**																		
18	BB			**1120**																		

* Cell S2, where "_" denotes a space in the text string.

Figure 4.4: Line Description identification and rationalisation process.

4.6.3.1 Identifying Line Descriptions and Capturing Areas, Stage 1

For Stage 1 of the procedure, cells E2 to I2 (Figure 4.4) show a small sample of the standard VOA Accommodation Use Code descriptions (AUCs). In practice, the full set of 115 descriptions are ranked (highest on the left) according to the summed area of Line Entries attributable to them within the SMV database table. The descriptions that appear and their ranking will depend upon the make-up of economic activities in the Billing Authority SMV being analysed. Some AUC descriptions may appear within a given SMV, though they might have no recorded taxable area. Equally, some descriptions might not appear at all.

The formulae held in columns E to I seek a perfect match of values in column C and row 2. This occurs in cell E3, where "Production Area" in C3 equals "Production Area" in E2, so a value of "1" is returned in cell E3. This is repeated for each column E to I and each row 3 to 8 and 10 to 14. Stage 1 of the procedure initially attempts to identify Line Entries that perfectly match VOA AUC descriptions and it can be seen that some Line Descriptions are not identified.

Cell F4 does not return a positive result because "Offices" (cell C2) is not a perfect match to "Office" (cell F2), thus this Line Description is not identified. The Line Description in cell C11 is not identified because, although the cell contains the words "Offices/Storage", the cell value does not perfectly match any cell in E2 to I2. The Line Descriptions in cells C8 and C14 are not identified because "Timber Yard" is not a standard VOA AUC description and consequently a match is not sought during Stage 1 of the procedure.

Cells J3 to J8 and J10 to J14 sum the cells to their left (columns E to I). For premises AA four Line Descriptions have been identified, whilst BB has two identified. Column L multiplies the areas held in column D by the contents of column J, to indicate the area of the Line Description that has been captured. In both premises, even though the Staff Toilets have been identified, no area has been attributed to these Line Entries, by the VOA, so no area has been captured. Cells L9 and L15 sum the areas captured. The subtotals of areas captured, during Stage 1, are different, due to the "Offices/Storage" of premises BB not being captured. Column M indicates whether a Line Entry needs to progress to Stage 2 of the procedure. All Line Entries where the Line Description has been identified in Stage 1 are designated "Direct Match", in terms of the method of identification.

4.6.3.2 Identifying Line Descriptions and Capturing Areas, Stage 2

Stage 2 of the process matches character strings in the Line Description to the sample character strings shown in cells N2 to S2. This process uses the SEARCH(…) and NOT(SEARCH…) operations within Microsoft Excel 2003.

The search for character strings begins by looking for matches, or very close matches, to strings formed by AUC descriptions. Premises BB only needs to have two Line Entries captured and this is partly achieved by matching the string "Office" in cell O2 with the string "Office" within the text "Offices" held in cell C4.

To gauge the success, or failure, of determining search criteria, the count of lines identified and the total area captured are monitored for increases in each. But, as the ultimate aim of Stage 2 is to capture as much area as possible, an increase in the total area captured takes precedence over the number of Line Descriptions identified. This priority is applied because identifying Line Descriptions with nil floor area is of little use when applying Energy Intensities to floor areas.

In row 8, "Timber Yard" is also identified by matching the character string "_yard" (where _ represents a space in the text) to "Timber Yard", ignoring the "Timber" part of the overall string. For premises AA, Stage 2 has captured 200m^2.

In row 11, the Line Description "Office/Storage" is identified twice: first by the search for the character string "Office" and second by the search for the string "Storage". Each identification returns a positive result, so the sum of cells N11 to S11 is "2". Because it is not possible to know exactly how much of the area is "Office" or how much is "Storage", the Line Entry is designated as "Not Allocated". Wherever the value calculated in column T (excluding the subtotals) is greater than 1, the Line Entry is designated as "Not Allocated". Stage 2 captures only the Timber Yard, in premises BB, with an area of 100m^2.

The choice of search strings that are not AUC descriptions is determined by querying the Rating List and SMV data tables to rank Line Descriptions according to their summed areas. This is done without sorting the data according to the premises or PD Code in which the Line Description appears. By working down the ranked list, it is possible to identify whole descriptions, or text strings, for which a search should be made within Stage 2. Care must be taken to ensure that identifying a new non-AUC description text string does not reduce the total area captured by the combination of previously identified strings. For example within the Leicester City data, the non-AUC description "Offices" (identified using the string "Office") has a total area of 125,344m^2. However, there is also a description "Sorting Office" which accounts for 7,653m^2. To ensure that both areas are captured, it is necessary to use the NOT SEARCH operator for "Sorting Office", when searching for the string "Office", in Stage 2. If this is not done, the Line Description will be identified twice in Stage 2 and the value held in column T (Figure 4.4) will be "2", thus failing to capture the area of any corresponding Line Entries.

It was found that Stage 2 presented a situation of diminishing returns on the investment of time and effort when establishing the search strings used to identify Line Descriptions. With this methodology, the user must decide upon a point at which the area allocated by a new Line Description identification search no longer adds a sufficiently-large area to the total allocated to be deemed worthwhile. By the time the methodology had allocated 95% of Leicester's total floorspace, there was a progressive tailing-off in the rate at which Line Descriptions could be identified with sufficiently-large increases in the total allocated area. Once 96% of the total floorspace of Leicester City had been captured, the generation of new search strings occasionally caused some previously-allocated areas to be lost, for only a minor increase in the total area allocated. This situation was mostly due to identification of multiple strings, as described in the previous paragraph.

The complete list of search criteria used in Stage 1 and Stage 2, can be found in Appendix G. As explained above, Stage 2 uses the SEARCH(…) and NOT(SEARCH…) operations to identify Line Descriptions. There are a few exceptions where exact matching/not matching of cell values is used for Line Descriptions that do not conform to recognised VOA AUC descriptions. For simplicity, and to maintain the consistency of Stage 1 being used to identify exact AUC descriptions only, these exceptional exact match procedures are applied in Stage 2.

Returning to the example in Figure 4.4, at the conclusion of Stages 1 and 2, premises AA have had all Line Descriptions identified (6 of 6) and all 1310m^2 of their area captured. Premises BB have had 4 of 5 Line Descriptions identified and consequently only 1120m^2 area captured, due to the mixed Line Description "Offices/Storage". But it may be said that the nature of the activity of both of these premises has been identified, even though these can only be accurately attributed to 1120m^2 of its total 1310m^2. From this, it may be seen that the nature of all of the Line Entries of both premises have been identified, but not all of the area has been captured.

4.6.3.3 Recording of Output from Stages 1 and 2

The final stage of identifying and cleaning the premises' Line Descriptions was to generate a database table of Line Entries and the "New Line Description" (LineDescNew) to which their Line Description has been allocated. In the case of a Line Entry with an Accommodation Use Code (AUC) description, this New Line Description is the AUC description. In other cases, the New Line Description is the text held in the "Search Line Description" given in the table of search terms (see Appendix G). As these New Line Descriptions are not always perfectly useful for describing a Line Entry's activity, the database table generated is an interim data storage medium.

A second table, recording whether/how each Line Description had been indentified and the floorspace captured, was also created. This second table also records to which category – Internal, External etc. – the Line Entry was allocated and thus where its floorspace can be placed, in relation to the building envelope (if there is one) associated with premises.

4.6.3.4 Analysis of Output of Stages 1 and 2

By interrogating the data in the new table (above), a summary of how Leicester City's floorspace has been identified, per PD Code, can be shown in Figure 4.5, below. The results are ordered according to the total area identified in Stage 1. It should be remembered that, although premises and their floor area are grouped by PD code, the space use identification process is based upon Line Entries, not PD codes.

Figure 4.5 shows that the bulk of premises' areas can be captured by identifying the descriptions associated with Accommodation Use Codes, with a generally diminishing area of floorspace identified by the stages of string matches.

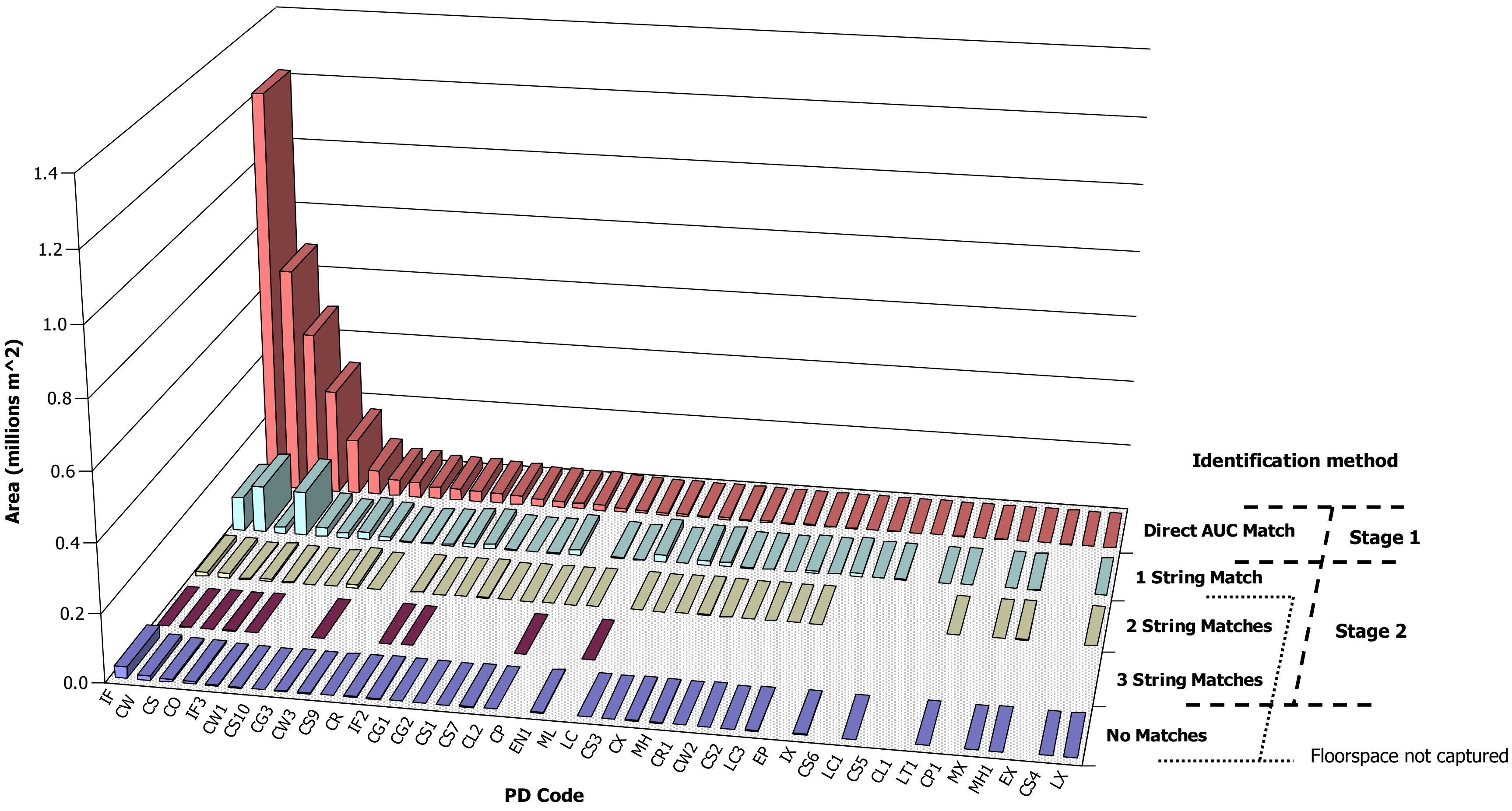

Figure 4.5: Summary of total floorspace identified in Stages 1 and 2, classified by PD Code.

PD Codes IF (Factories), CW (Warehouses), CS (Shops), CO (Offices) and IF3 (Workshops) account for most (79.9%) of the captured floorspace of the Leicester SMV. For each PD Code, the majority of floorspace is captured as a direct match to AUC descriptions (81.2%), with the next largest portion (14.8%) of the total area being captured as a single-match string in Stage 2. This is most significant in PD Codes CW and CO. For Leicester, the overall result of Stages 1 and 2 of the Line Description identification procedure is that a fraction over 96% of the total floorspace, listed in the SMV (filtered by the Rating List), has been captured.

In addition to the floorspace captured, there are also a further 1,822 Line Entries with identified Line Descriptions, but for which there are no recorded areas. The description "Staff Toilets" accounts for 81% of these Line Entries, as this use of space is not generally rateable and thus frequently has no recorded area. The remaining 19% is made up of plant/boiler rooms, storage-type spaces and public toilets, plus a few others.

Analysis of the 4% of total floorspace that has not been captured indicates that the two-match Line Entries account for 42% and the three-match for just over 1%. The remaining 57% have not had their Line Descriptions identified and are made up of Line Descriptions that are frequently unique and sometimes have no recorded area. This 57% without identification accounts for a mere 2.2% of total floorspace in the Leicester SMV. Also, some of the descriptions are not indicative of the activity of the recorded area and appear to be used more as a means of identifying spatial location within premises. The analytical value of the unidentified Line Descriptions is thus extremely limited.

Figure 4.6, below, shows how space has been allocated in terms of whether it can be classified as internal or external. Table 4.4 and Table 4.5, above, show how AUC descriptions have been classified for this purpose. Note that Figure 4.6 also depicts areas that could be classed as internal, or external, as well as areas that cannot be defined as either, due to a lack of information. In Figure 4.6, the areas shown as "Not Allocated" are the same as the sums of areas in Figure 4.5 shown as "2 String Matches", "3 String Matches" and "No Matches" (i.e. the areas not captured in Stages 1 and 2 of the process). Note also that the *x* axis has altered, due to the results being ordered according to the total area allocated as "Internal", per PD Code.

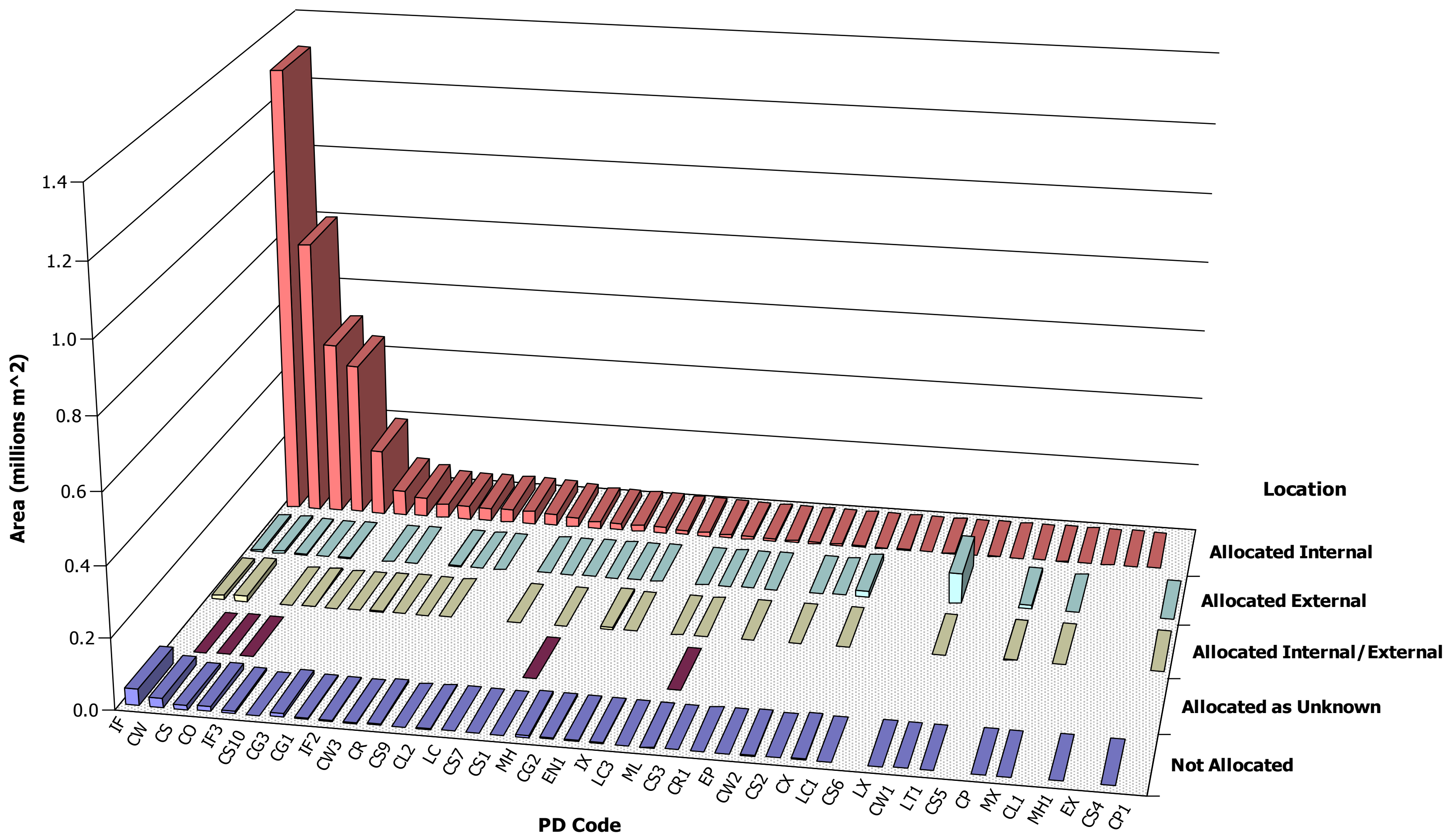

Figure 4.6: Summary of allocation of total floorspace to internal, external etc, by PD Code

Figure 4.6 clearly shows that space use in the City of Leicester is dominated by a small number of premises types and that the bulk of these premises' areas are internal (see also, Table 4.9, on page 134). Only PD Code CW1 – Land Used for Storage – has large external areas, as one would expect. Space allocated as "Unknown" appears in only five PD Codes and with negligible areas. "Internal/external" spaces can be found in 23 of the 41 PD Codes, but again these represent small percentages of each PD Code's total area. PD Codes CP and CP1 are shown as areas, though they are mostly made up of parking "spaces", as indicated by the existence of premises that are single car parking spaces with an area of "1", which clearly cannot denote a solitary square metre of area into which a vehicle must fit. Fortuitously, parking spaces can be allocated as "External" and therefore have no internal gains, though they may still have associated electricity consumption for lighting, access control barriers and so forth.

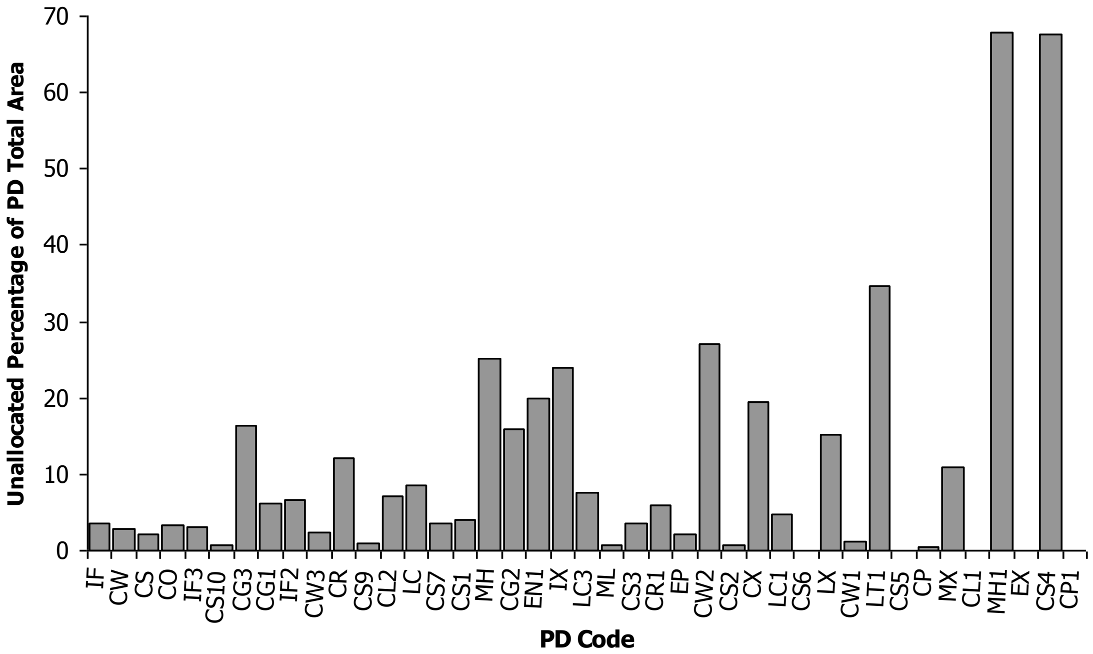

Figure 4.7: Non-allocated area as a percentage of total area of each PD Code

Figure 4.7 shows the percentage of each PD Code's total area that remains "unallocated" at the end of Stage 2. For clarity, the *x* axis of Figure 4.7 is in the same order as Figure 4.6, indicating that the five PD Codes (the five left-most) that constitute the majority of Leicester floorspace, also have low percentages of unallocated space.

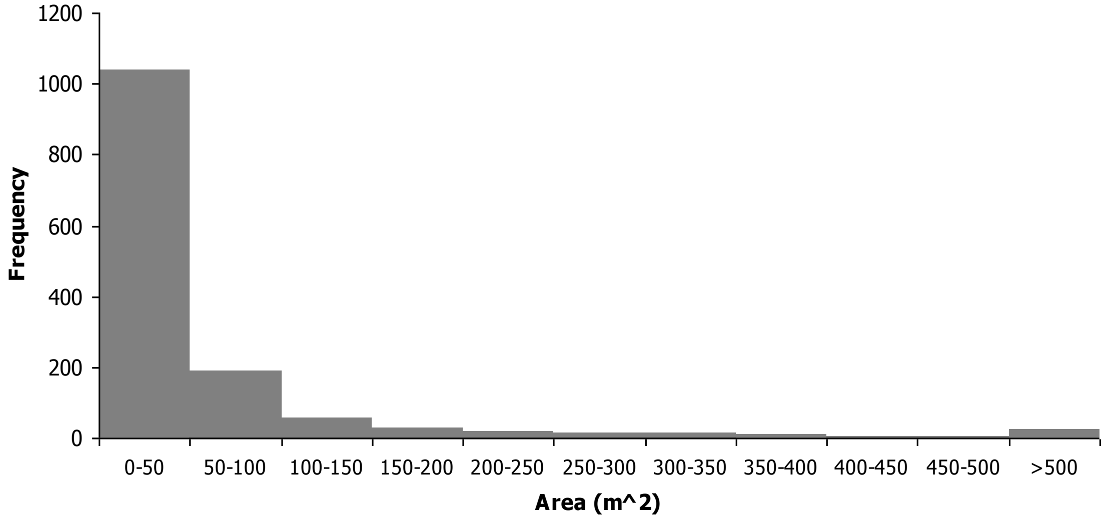

Figure 4.8: Areas of unallocated Line Entries

Figure 4.8 shows that the bulk of the Line Entries with unidentified Line Descriptions have areas of less than 50m^2 and further examination of the data reveals that 181 of these have no recorded area. The Line Entries with areas greater than 500m^2 constitute 35% of the total unallocated area. Taken together, Figure 4.5 and Figure 4.8 indicate that although 2.2% of the total floorspace of the Leicester SMV is not captured, this is made up of only 1,400 Line Descriptions and that most of these have small areas, though a small number have moderately large areas, with the largest being 6,254m^2.

The complete breakdown of space allocation is shown in Table 4.9, below. The order of presentation follows that of Figure 4.6, on page 131.

Table 4.9: Allocation of total floorspace (m^2) to internal, external etc, by PD Code.

	Allocated						
PD Code	Internal	External	Internal/External	Unknown	Sum	Not Allocated	Sum
IF	1302527	5895	13264		1321686	47167	1368853
CW	799679	6925	16024	116	822744	25102	847847
CS	503261	4002		92	507355	11398	518753
CO	444505	1256	420	198	446378	14881	461260
IF3	190433	1908	1900		194241	6273	200514
CS10	71298		205		71502	450	71953
CG3	56182	232	685		57099	11091	68190
CG1	40037	317	1478		41831	2782	44613
IF2	38719		1685		40403	2857	43261
CW3	37896	1361	327		39584	957	40540
CR	37133	114	23		37270	5096	42366
CS9	37067	422			37489	353	37842
CL2	34311				34311	2602	36913
LC	28164	390	285		28840	2734	31573
CS7	19413	41			19454	733	20187
CS1	18427	43	32	1087	19589	804	20393
MH	17948	114			18062	6043	24105
CG2	17023	171	6026		23221	4366	27586
EN1	12446	125	326		12898	3233	16131
IX	11387				11387	3598	14985
LC3	8665	13	26		8704	714	9417
ML	7401	52	108	12	7573	61	7634
CS3	6695	15			6709	254	6963
CR1	5565	36	1218		6819	433	7251
EP	5017				5017	114	5131
CW2	4762	96	465		5323	1965	7287
CS2	3477	3			3480	21	3502
CX	2726	15399	518		18643	4492	23134
LC1	2235				2235	113	2348
CS6	2019				2019		2019
LX	1188				1188	214	1403
CW1	991	88591	399		89981	1167	91147
LT1	881				881	468	1349
CS5	875				875		875
CP	732	9893	126		10751	46	10797
MX	611				611	74	686
CL1	581	161	15		756		756
MH1	555				555	1175	1730
EX	157				157		157
CS4	62				62	131	193
CP1		461	2		463		463

4.7 Mapping SHU Appliance Energy Intensity Profiles onto Leicester VOA Data

This section describes the methodology for inferring Energy Intensities (kWh/m^2/yr) in the various New Line Descriptions and their areas, in the cleaned VOA datasets. The mean Energy Intensities of electrical appliances derived from analysis of the SHU data in Section 3.8, above, are mapped onto the VOA New Line Descriptions identified in Section 4.6.3, above. These Energy Intensities may then be applied to each Line Entry's recorded area to estimate the electricity consumption of appliances in that Line Entry.

4.7.1 Generating the SHU:VOA Map

A flowchart of the procedure for generating the SHU:VOA Map is shown in Figure 4.9. on page 137. The cleaned data, from the Rating List and SMV (at the start of the schematic) are the output of the VOA data preparation stage, for which there is a flowchart shown in Figure 4.2 on page 116.

In the process of cleaning and rationalising the Line Descriptions in the SMV (See Section 4.6.3), there was a diminishing return on the effort expended to get the data to a more suitable and usable state. To improve work efficiency when applying the SHU-derived Energy Intensities of Room Uses to the output of Section 4.6.3, the New Line Descriptions (LineDescNew) were ranked according to their summed Line Entry areas. This method provides an initial means of prioritising the order in which to apply the SHU-derived Room Use Energy Intensities (EI) to PD code & LineDescNew combinations. Also, as described in Section 4.6.1, Line Descriptions are judged to be more accurate than other descriptions of activity. This methodology uses the prefix of PD code and suffix of LineDescNew, only because this is generally the hierarchy of space use in buildings and premises. It also fits the Layers of Change model.

To generate the SHU:VOA map, the VOA Accommodation Use Codes (AUCs) were given priority over the ranking of PD code & LineDescNew combinations, as the AUCs are the Line Descriptions most likely to appear in VOA SMV datasets.

By applying SHU EI values to these AUC Line Descriptions, first, the amount of work may be reduced as AUCs account for the bulk of the SMV floor area. All Line Descriptions that are identified as being "External" did not have SHU values mapped onto them, as these would not have internal gains – this applies to both AUCs and the additional New Line Descriptions described in Section 4.6.3.

Table 4.10, below, gives the list of AUC descriptions: a grey-shaded cell indicates where an AUC is assumed to be located.

Table 4.10:Assumed locations of spaces, as applied to SMV.

AUC Description	Internal	External	AUC Description	Internal	External
All main areas	●		Locker room	●	
Amusement Arcade	●		Lounge	●	
Ancillary Office	●		Lower Ground Floor sales	●	
Atrium	●		Mess/Staff room	●	
Banking Hall	●		Nursery	●	
Bar	●		Office	●	
Boardroom	●		Other Retail Zone	●	
Canopy	●	●	Plant room	●	
Canteen	●		Portable Building	●	
Cells	●		Production Area	●	
Changing room	●		Public toilets	●	
Chill store	●		Reception / Entrance	●	
Classroom	●		Remaining Retail Zone	●	
Cold store	●		Restaurant	●	
Committee Room	●		Retail Area	●	
Computer room	●		Retail Zone A	●	
Covered Area	●	●	Retail Zone B	●	
Filling Station shop	●		Retail Zone C	●	
First floor production area	●		Retail Zone D	●	
First floor sales	●		Retail Zone E	●	
Food Processing Area	●		Retail Zone F	●	
Function Room	●		Sales Display area	●	●
Garage	●	●	Shed	●	●
Gatehouse	●		Showers	●	
Glasshouse	●	●	Showroom	●	
Ground Floor Sales	●		Staff toilets	●	
Health Centre	●		Storage	●	
Hi Tech Accommodation	●		Store	●	
Internal storage	●		Strongroom	●	
Kitchen	●		Surgery	●	
Laboratory	●		Warehouse	●	
Lift Shaft	●		Works office	●	
Loading Bay	●	●	Workshop	●	
Lock Up Garage	●	●			

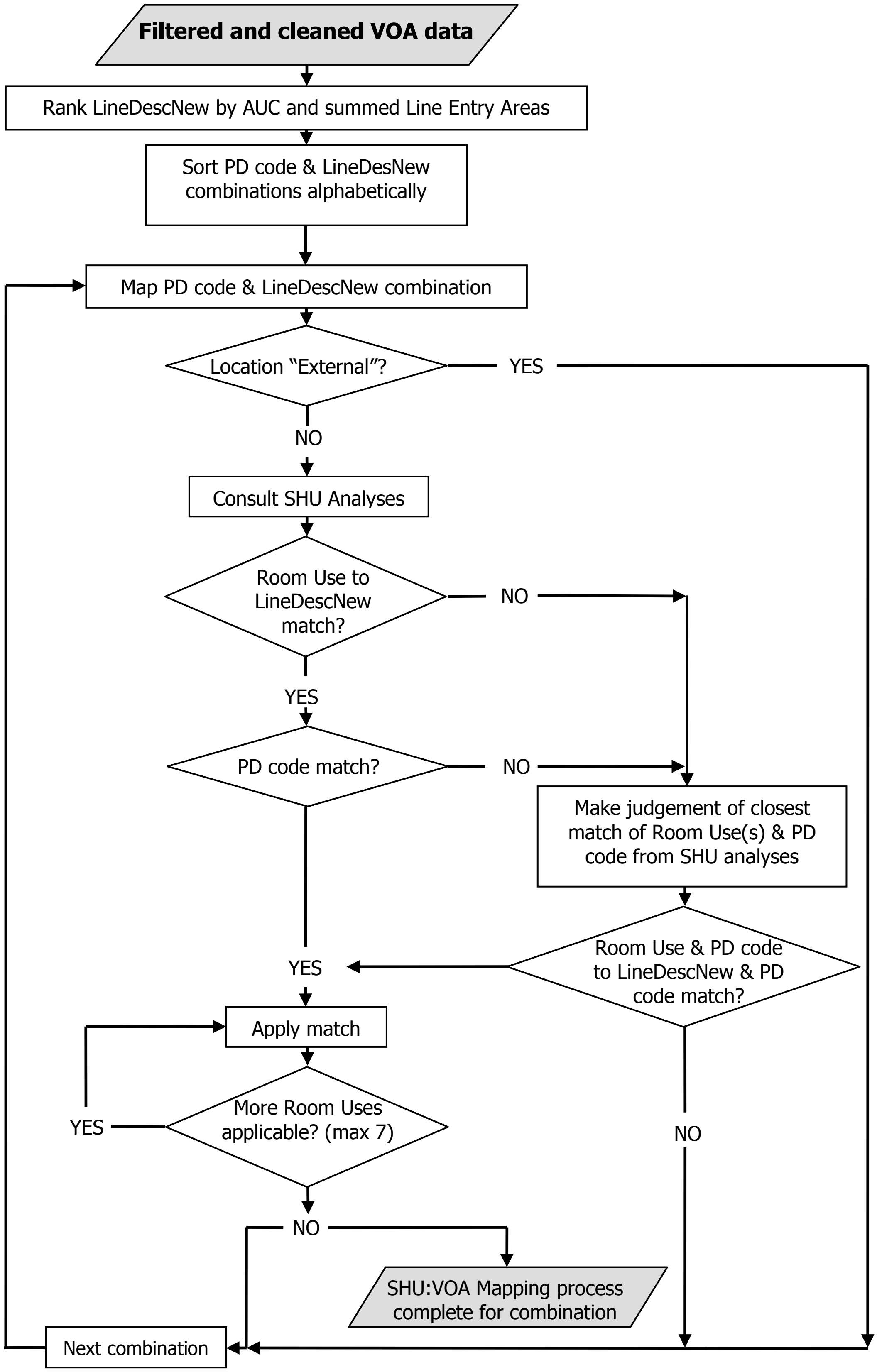

Figure 4.9: Flowchart of procedure for generating the SHU:VOA Map.

A sample of the mapping of SHU Energy Intensity values onto the VOA SMV Line Entries, using a spreadsheet, is shown in Figure 4.10. Note that the table headings are split between light and dark grey. The columns with the light grey headings are derived from the SMV and Rating List, as modified by the procedures described in Section 4.2.3, above. The columns with dark grey headings are drawn from the cleaned and updated SHU dataset.

The VOA data inputs are generated by querying the cleaned Rating List and the cleaned and rationalised SMV data tables. From these are drawn the summed Line Entry areas of all the PDcode&LineDescNew combinations, grouped by PD code. The database query output is transferred to a spreadsheet, where it is ranked according to the Allocation Code (column G, in Figure 4.10), to present the PDcode&LineDescNew combinations ordered so that VOA Accommodation Use Code descriptions take precedence in the mapping procedure. The PDcode&LineDescNew combinations are then sorted according to their percentage of the total area of the SMV (column A) and by PD Code (column H).

The method of generation of the SHU:VOA Map is partly dependent upon the Line Descriptions and Primary Description (PD) codes present in the VOA datasets. These data appear to be partly, or wholly, dependent upon the choices made by VOA surveyors, or those who input data into the databases, as is evidenced by the range of descriptions found in the Line Descriptions field and the mismatches of Primary Descriptions and PD code. If surveyors do have a significant influence on the Line Descriptions used, the Map is likely to develop in a slightly different way, depending upon the influence of each surveyor’s use of Line Descriptions. There may also be patterns of description usage within local Valuation Offices. The methodology copes with these potential influences and patterns through the use of the ranking of the sum of Line Entry areas, per Line Description, as the ranking would alter according to the prevalence of description usage.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
									SHU RmUse *						
Sum Of LineDescNew Area as % of total SMV Area	Sum Of LineDescNew Area (m^2)	LineDescNew	Sum Of LineDescNew Area per PD (m^2)	Location Code	% of total SMV	Allocation Code	PD Code in Rating List	PD Code in SHU	1	2	3	4	5	6	7
22.20842	915455	Production Area	424	1	0.01028	1	CG1	CG1	carser						
22.20842	915455	Production Area	3337	1	0.08096	1	CG2	CG1	carser						
22.20842	915455	Production Area	275	1	0.00667	1	CO	IF3	proc						
22.20842	915455	Production Area	20478	1	0.49678	1	CW	IF3	proc						
22.20842	915455	Production Area	831615	1	20.17452	1	IF	IF	proc						
17.36689	715882	Warehouse	487	1	0.01182	1	CG1	CG1	store						
17.36689	715882	Warehouse	1515	1	0.03676	1	CS	CS	store						
17.36689	715882	Warehouse	1637	1	0.03972	1	CS10	CS	store						
17.36689	715882	Warehouse	595836	1	14.45464	1	CW	CW	store						
17.36689	715882	Warehouse	2554	1	0.06197	1	CW3	CW	store						
17.36689	715882	Warehouse	99518	1	2.41426	1	IF	IF	store						
16.31461	672506	Office	1912	1	0.04637	1	CG1	CG1	off	prin	mtg	teach	circ		
16.31461	672506	Office	388218	1	9.41794	1	CO	CO	off	prin	sec	mtg	cmp	teach	circ
16.31461	672506	Office	86261.92	1	2.09276	1	CW	CW	off	prin	mtg	cmp	teach	circ	
16.31461	672506	Office	697	1	0.01690	1	CR	CR	off	teach					
0.54317	22390	External storage	180	2	0.00436	1									
0.3750	1546	Cold store	155	1	0.00375	1	CR	GENERIC	froz						
0.3750	1546	Cold store	459	1	0.01114	1	CS	GENERIC	froz						
0.3750	1546	Cold store	431	1	0.01045	1	IF	GENERIC	froz						
0.03652	1506	Unclassified area	198	4	0.00480	1									
0.03015	1243	Shed	113	3	0.00275	1	CG2	CW	store						
0.54317	12911	Vehicle Repair Workshop	9587	1	0.23258	2	CG1	CG1	carser						
0.03652	12911	Vehicle Repair Workshop	950	1	0.02306	2	CG2	CG1	carser						
0.03015	12911	Vehicle Repair Workshop	361	1	0.00876	2	CW	CG1	carser						

Figure 4.10: Sample of SHU onto VOA Map.

* SHU RmUse: carser = car servicing; circ = circulation; cmp = computing; froz = frozen storage; mtg = meetings; off = office work; prin = printing; proc = process; sec = security; store = storage; teach = teaching.

Once the order of prioritisation has been applied, the procedure becomes one of mapping Energy Intensity values, from the SHU data analyses, onto the VOA Line Entries. The key objective, when mapping SHU Room Uses onto the VOA Line Entries, is to adequately represent the appliances that are likely to appear in the spaces described within the SMV, and thus enable the estimation of appliance electricity consumption and consequent internal gains.

In some cases there is an exact match, for example IF and "proc" (in the SHU) maps onto IF and Production Area (in the SMV). However, in a number of cases, there is no direct match, due to a lack of data in the cleaned SHU datasets. Where this occurs, it is necessary to apply informed judgement and map the closest reasonable match from the SHU analyses, onto the SMV PDcode&LineDescNew combination. This method is used quite extensively in the mapping procedure. For example, the first row of Figure 4.10 shows the SHU CG1 (Vehicle Repair Workshop) and "carser" (car servicing) combination mapped onto the SMV CG1 and "Production Area" combination. In this instance, a reasoned judgement has been made that "car servicing" in the SHU CG1 class is representative of "Production Areas" in SMV Line Entries, for the Primary Description "Vehicle Repair Workshop". Near the bottom of the Figure, it can be seen that the LineDescNew "Vehicle Repair Workshop" also has the SHU combination of CG1&carser mapped onto it, because the LineDescNew "Vehicle Repair Workshop" is assumed to be the same as "Production Area", for this Primary Description class, in the SMV.

This use of non-straightforward matches of SHU to VOA, is not as problematic as might first be imagined, as the floorspace mapped in this way represents less than 14% of the total area of the Leicester SMV. The largest area type mapped using a non-straightforward match, is "Ground Floor Sales" in PD code CS10, representing 44,920m^2 of floorspace and 1.09% of the Leicester SMV total area. In this particular instance, reasoned judgement dictates that the sales (sal) spaces of Shops (CS) in the SHU are representative of the "Ground Floor Sales" areas described in the SMV.

For some VOA PDcode&LineDescNew combinations there is more-limited information (due to sample sizes) that can be drawn from the SHU analyses. For some of these VOA combinations the information in the SHU data is such that a "GENERIC" value, consisting of all examples of that RmUse in the SHU (i.e. an average for the RmUse across the whole of the cleaned SHU dataset), is generated and applied to the VOA LineDescNew. Within the mapping procedure, 18% of SMV PDcode&LineDescNew combinations have a GENERIC Room Use EI value mapped onto them, from the SHU dataset. This 18% amounts to only 151,000m^2 of the floorspace captured from the SMV.

In Figure 4.10, it may also be seen that, in the columns headed "SHU RmUse" and numbered 1–7 (columns J to P), some VOA PDcode&LineDescNew combinations have more than one SHU PDcode&RmUse combination. For example, the VOA combination of CO and Office, has the SHU RmUses "off", "prin", "sec", "mtg", "cmp", "teach" and "circ" (all from PD code CO) mapped onto it. This combination of SHU RmUses is designed to overcome instances where the SHU data indicate that Room Uses appear in the stock, but the VOA does not contain a similar and proportionate number of these Room Uses. A particular case in point would be print rooms (RmUse "prin") appearing in 15 of 66 Office premises in the SHU dataset, but not appearing at all in Office premises in the Leicester SMV. It is unlikely that there are no print rooms in Leicester Office premises, so it is sensible to assume that this Room Use is given the Line Description "Office" in the SMV. There are six instances of "printing" appearing in the SMV, but these are all in either PD code IF or IF3 and are likely to have been classed as "process" activity spaces ("proc") in the SHU nomenclature.

Towards the bottom of Figure 4.10, there are entries for "External Storage", "Unclassified Area", and "Shed". These show how the Location Code (see Section 4.6.3.3 for details) is used to determine whether the mapping procedure needs to be applied, depending upon the nature of spaces. The mapping can be applied to spaces likely to have internal gains (code 1), external spaces (code 2), and internal/external spaces that might have internal gains (code 3), as required. The mapping cannot be applied to spaces whose location cannot be defined due to a lack of information (code 4), but these do not represent large areas, as indicated in Figure 4.6.

4.7.1.1 Accounting for "Hidden" Space Uses

The SHU:VOA map also forms part of the process used to make allowances for the differences in floor areas that result from the use of the Net Internal Area (NIA) measurement convention, for some premises types. A consequence of this is that some of the activities in the space are "hidden". NIA does not specifically measure for some space uses, such as "circulation", particularly where these are for the exclusive use of the premises' occupant. By including the SHU Room Use "circ", circulation space can be taken into account, as a proportion of the NIA of a Line Entry, together with its energy intensity.

This inclusion of "circ" with SHU Room Uses mapped onto a LineDescNew, is also useful for some premises types that are not measured to NIA. An example of this can be seen in the "Office" LineDescNew for the VOA PD code "CW" (in Figure 4.4, above), which is measured to the GIA convention. Here, it is assumed that the VOA area measurement for the "Office" includes some circulation space joining rooms within the space recorded as "Office". By including "circ" within the map, for "Office" space in such premises, the "hidden" circulation can be inferred and have its energy intensity characteristics estimated.

4.7.2 Applying the SHU:VOA Map to the Leicester City Datasets

To apply the SHU:VOA map to the Leicester City VOA data, the information shown in columns A to H in Figure 4.11 is extracted from the cleaned and rationalised VOA data tables and exported to a spreadsheet. The information exported consists of the following:

Column	Content
A	The sum of all Line Entry areas corresponding to the BA Ref (m^2)
B	The BA Ref - the unique identifier for each premises
C	The Primary Description code of the premises
D	The number of the Line Entry in those premises
E	The Line Description after cleaning and rationalisation (LineDescNew)
F	The area of the Line Entry (m^2)
G	The Location Code for the Line Entry (0 to 4)

Within this first sheet of the workbook, named "Result", the following function is performed:

Column	Content
H	The concatenation of the contents of column C and column E (PDCode&LineDescNew)

	A	B	C	D	E	F	G	H	I	J
	SumOfArea	**BA Ref**	**PDCode**	**Line**	**LineDescNew**	**Area**	**LocationCode**	**Concatanated**	**SHUArea**	**SHUkWh**
1	589.5	5005XXXXXX	CW	1	Office	241.9	1	CWOffice	745.5	63300
2	589.5	5005XXXXXX	CW	2	Internal storage	347.6	1	CWInternal storage	12081.37	396875
3	790.83	506XXXXXXX	CX	1	Studio	333.96	1	CXStudio	54056.59487	4557229
4	790.83	506XXXXXXX	CX	2	Storage	347.4	1	CXStorage	36137.35018	1426745
5	790.83	506XXXXXXX	CX	3	Office	89.87	1	CXOffice	106072.0283	6972617
6	790.83	506XXXXXXX	CX	4	Toilets	19.6	0	CXToilets	0	0
7	20.78	516XXXXXXX	CO	1	Office	20.78	1	COOffice	59573.65494	5303133
8	200.3	600XXXXXXX	LC	1	Production Area	86	1	LCProduction Area	857.04	30462
9	200.3	60XXXXXXXX	LC	2	Production Area	114.3	1	LCProduction Area	857.04	30462
10	201.06	60AXXXXXXX	IF3	1	Workshop	201.06	1	IF3Workshop	857.04	30462
11	114.07	400XXXXXXXX	CS	1	Retail Zone A	34.63	1	CSRetail Zone A	36385.3212	6367594
12	114.07	400XXXXXXXX	CS	2	Retail Zone B	31.23	1	CSRetail Zone B	36385.3212	6367594
13	114.07	400XXXXXXXX	CS	3	Retail Zone A	10.66	1	CSRetail Zone A	36385.3212	6367594
14	114.07	400XXXXXXXX	CS	5	Internal storage	35.25	1	CSInternal storage	10472.17015	555374
15	114.07	400XXXXXXXX	CS	6	Kitchen	1.92	1	CSKitchen	1522.92	880663
16	114.07	400XXXXXXXX	CS	7	Staff toilets	0	1	CSStaff toilets	1117.0538	179904
17	6199	400AXXXXXXX	CO	1	Office	443.7	1	COOffice	59573.65494	5303133
18	6199	400AXXXXXXX	CO	2	Computer room/Server room	20.8	1	COComputer room/Server room	1352.662352	517334
19	6199	400AXXXXXXX	CO	5	Office	457.3	1	COOffice	59573.65494	5303133
20	6199	400AXXXXXXX	CO	6	External storage	35.1	2	COExternal storage	0	0
21	6199	400AXXXXXXX	CO	7	Restaurant	409.7	1	CORestaurant	925.2264	138998
22	6199	400AXXXXXXX	CO	8	Plant room	0	1	COPlant room	2425.76564	858570
23	6199	400AXXXXXXX	CO	9	Reception / Entrance	51.1	1	COReception / Entrance	2228.23639	185368
24	6199	400AXXXXXXX	CO	10	Office	698.3	1	COOffice	59573.65494	5303133
25	6199	400AXXXXXXX	CO	11	Store	37.2	1	COStore	3111.193776	110820
26	6199	400AXXXXXXX	CO	12	Office	1338.6	1	COOffice	59573.65494	5303133
27	6199	400AXXXXXXX	CO	13	Office	1403.6	1	COOffice	59573.65494	5303133
28	6199	400AXXXXXXX	CO	14	Office	1403.6	1	COOffice	59573.65494	5303133

Figure 4.11: Application of SHU:VOA Map to VOA Line Entries.

In the same workbook, a second sheet, named "RmUse", contains a lookup table of PD Code and RmUse combinations, from the cleaned SHU dataset. Together with each PDcode&RmUse combination, are the total area and the total appliance annual electricity consumption of all rooms in that combination. For example all "store" rooms in PD code CW (Warehouse) total area 10,472.17015m^2 and total consumption 55,5374 kWh.

A third sheet, named "Map", contains the SHU:VOA map.

To calculate the internal gains of a Line Entry, the following procedure is performed.

1. If the Location Code (column G in Figure 4.11) is equal to "1", the concatenated PDCode&LineDescNew is used as the lookup value in the sheet "Map". This searches for a match to the concatenated values of column H and column C (i.e. H&C) as indicated in Figure 4.10, above.

2. The SHU:VOA map looks, in the sheet "RmUse", for each of the PDcode&RmUse combinations listed in the "Map" sheet required to return a value for the area and electricity consumption of all RmUses indicated in the "Map".

3. The areas of all required RmUses and the consumption of all required RmUses are each summed and returned to the "Result" sheet, as indicated in Figure 4.11 by column I and column J, respectively.

The above returns the following, in Figure 4.11:

Column	Content
I	The sum of all areas, within the cleaned SHU dataset, as identified by the SHU:VOA map, applicable to the Line Entry
J	The sum of all appliance electricity consumption, within the cleaned SHU dataset, as identified by the SHU:VOA map, applicable to the Line Entry

An example of the application method would work as follows for the premises BA Ref 500XX00800, shown in Figure 4.11:

1. For each Line Entry

2. IF cell G1="1" THEN look-up contents of cell H1 ["CWOffice"] in sheet "Map", ELSE proceed to next row

3. G1="1", so, in sheet "Map", listed against "CWOffice", the look-up finds these SHU RmUses: "off", "prin", "mtg", "cmp", "teach", "circ"
4. Sheet "Map" concatenates the PD Code in SHU and the SHU RmUse (column I & column J) ["CWoff"]; column I & column K [CWprin"] … and so forth
5. Sheet "Map" searches sheet "RmUse" for a match to each PDcode&RmUse combination
6. The following values are returned:
    a. CWoff: Area 527.46; kWh 29391
    b. CWprin: Area 29.08; kWh 4617
    c. CWmtg: Area 101.4 kWh 5870
    d. CWcmp: Area 18.93 kWh 9205
    e. CWteach: Area 58.56 kWh 32
    f. CWcirc: Area 118.03 kWh 12686
7. Areas a to f are summed, to give 853.46 m^2
8. kWhs a to f are summed, to give 61801 kWh/yr
9. Sum of areas (step 7) is returned to cell I1, in Figure 4.11
10. Sum of kWh (step 8) is returned to cell J1, in Figure 4.11
11. Go to next Line Entry
12. Upon completion, the entire contents of the Result sheet is exported to allow further processing.

4.7.2.1 Line Entries without Areas

The sample of Line Entries in Figure 4.11 shows that some Line Entries have no recorded floor area. This situation occurs where a Line Entry records the existence and activity in a space, but does not attribute a floor area to the space, it does not have a taxable value. In Figure 4.11, there are Line Entries for "Staff toilets" and "Plant room" that do not require floor areas to be recorded; this is typical of the wider VOA SMV data. Using the space use profiles generated from the SHU data, it is possible to infer floor areas for these types of spaces; this is achieved in the following manner.

As with the SHU:VOA Map, described in Section 4.7.1 above, the SMV Line Entries with areas recorded as "0" are ranked according to the number of times they appear. This ranking takes into consideration the combination of the PD code and the LineDescNew, to allow the most efficient order for generating a lookup table of floor area inference factors. These inference factors are generated from the floor area profiles derived from the SHU space use analyses described in Section 3.4, above.

For the examples shown in Figure 4.11, the floor area value held in the "SumOfArea" (column A) is multiplied by the factor for the PDcode&RmUse combination that has been aligned with the PDcode&LineDescNew combination. For the Line Entry with a LineDescNew of "Staff toilets" in Row 17, this gives a value of 2.07m^2, based upon the SHU data Shops sample having an average of 1.69% of shop premises' total floor area classed as "washp", or WC/Showers etc. For the LineDescNew of "Plant room", in row 25, a value of 224.7m^2 is calculated. Clearly, where premises are small, this method could infer unfeasibly small areas. To overcome this, a minimum area is applied if the inferred area is smaller than the minimum. This minimum area is also taken from the SHU data area use profiles.

As with the generation of the SHU:VOA map, where the cleaned SHU data are unable to provide area factors and minimum values for the inferred areas, information from the nearest appropriate PD code is used. For example, for PD code CS7 (Showrooms), in the VOA, the floor areas of building services spaces are inferred from the SHU data for Shop premises (PD code CS), as these two premises types are likely to have similar percentages of their total floorspace used for building services. Floor areas are only inferred, in this way, for those Line Descriptions already allocated as internal containing the text strings "toilet", "plant" or "boiler", resulting in 10,112m^2 (GIA) of floorspace being inferred across 1,502 Line Entries (4.4% of the total number). The process does not infer areas for Line Entries that contain Line Descriptions that are not included in the SHU:VOA Map (Section 4.7.1).

4.7.3 Allowances for Net Internal Area

As described in Section 4.3 and, Table 4.1 above, the VOA measures some premises types to Net Internal Area (NIA) and others to Gross Internal Area (GIA). The original SHU surveys used the GIA convention, so it is necessary to adjust the areas of some premises types, in the VOA data, to allow the two datasets to align properly. The adjustment is applied after the inference of areas for LineDescNew containing "toilet", "plant" and "boiler". However, these three types of inferred areas are not adjusted, as they are already based upon SHU GIA measurements.

A table of adjustment factors (or ratios) for each Primary Description code was created, based upon the classification of premises in Bruhns et al (2000, Table 1, page 654). As Bruhns et al required Gross External Area, the ratios applied to the areas recorded in the VOA data, have been adjusted to align with this research's requirement for GIA. A list of the adjustment factors can be found in Appendix G. The area adjustment factor was applied to each eligible Line Entry's floor area, not to the premises, as a whole and the factor was applied regardless of whether the Line Entry's Line Description had been identified in the process described in Section 4.6.3, above.

The NIA to GIA adjustment procedure affected 23,005 Line Entries (67.7% of the total) and resulted in an additional 66,257m^2 of floorspace (1.65% of the total area captured or inferred).

4.8 Calculation of Appliance Electricity Consumption and Internal Gains for Leicester City

Values for the appliance electricity consumption of the Line Entries in the Leicester SMV are generated by multiplying their captured/inferred floor areas (see Sections 4.6.3, 4.7.2.1 and 4.7.3, above) by the energy intensities derived from the SHU data analyses (Section 3.8). Where the SHU:VOA map amalgamates multiple SHU Room Uses into a single VOA PDcode&LineDescNew combination, the resultant Energy Intensity is a mean for all the included Room Uses. This Energy Intensity is applied to the floor area of each Line Entry with a Location Code of "1", after the inference and NIA to GIA conversion processes described in Sections 4.7.2.1 and 4.7.3, respectively.

4.9 Inferring Appliance Electricity Consumption for End Use Classes and Used For Groups

In addition to calculating an estimate of the electrical consumption of appliances in each identified and captured/inferred Line Entry, this research also apportions the consumption to one of the 14 End Uses recorded in the SHU data (the balancing figure End Use is not included). In this way, it becomes possible to infer the types of appliances (the End Uses) that are consuming electricity in the Line Entries of the SMV. To this end, the SHU:VOA map, described in Section 4.7.1 above, is also used to attribute the End Uses of appliance consumption, identified in the analyses of the SHU data (Section 3.9), to the Line Entries of the Leicester City SMV. The map is used to extract values for each End Use, in each Room Use in each available PD code, from within the SHU analyses, and apply it to the floorspace of each Line Entry.

The VOA side of the Map acts as a look-up for the PDcode&LineDescNew combination and each equivalent SHU PDcode&RmUse combination to find the consumption of the 14 End Uses. The consumption of each End Use, in each SHU PDcode&RmUse combination, is divided by the total area of each combination. As not all rooms of a particular PDcode&RoomUse combination will contain all types of End Use, care was taken to ensure that the total area of the relevant SHU PDcode&RoomUse combination was used as the denominator, not the sum of the area of rooms in which the End Use appears in the SHU PDcode&RmUse combination.

The result of this process is used to create a database table that attributes appliance electricity End Use consumption to the Line Entries of the Leicester SMV.

To make use of the Used For groups, described in Section 3.10, the above process is repeated for the 18 groups and a corresponding database table produced.

4.10 Summary of Chapter 4

Chapter 4 has described how the Valuation Office Agency data for the test urban area were prepared, ready for the application of Energy Intensities and so forth, derived from the analyses of the SHU datasets (Chapter 3).

The early sections of the chapter described how the VOA data required some degree of filtering, to ensure that only unique and current premises were included in the later stages of the methodology. Attention was also paid to the discrepancies that were found between the recorded "Total Area" of premises compared to the sum of each premises' Line Entry areas. Although the overall difference was small, a few premises had differences in excess of 20% of their Total Area. In view of these differences and that valuations are based upon each Line Entry, not the Total Area field, the sum of Line Entry Areas was taken as being the actual total area in use within premises, rather than the premises' recorded Total Area.

Cleaning and rationalisation of the Line Descriptions reduced the number of variations in descriptions of space use, to make analysis both simpler and more meaningful. Apart from the accepted VOA AUC descriptions, a number of additional descriptions were identified as being common enough to expand the applicability of the outputs of the SHU analyses to otherwise unidentified floorspace in the Leicester SMV. All of the rationalised Line Descriptions, AUCs or not, were then attached to the VOA SMV Line Entries, and taken forward to later stages in the methodology. Overall, 96% of the SMV floor area was identified using 122 descriptions, with two AUCs not having any recorded area in the Leicester SMV. Ninety percent of the floorspace that was captured was identified using the standard VOA Accommodation Use Code descriptions, or cleaned versions of these.

After capturing the floorspace of most of the internal areas of the SMV premises, the energy consumption of appliances was calculated, using the profiles generated from the analyses of the SHU datasets. Further refinements enabled floorspace of non-core support spaces to be inferred for a number of Line Entries that had no recorded area. Also, Line Entry Areas, that the VOA measures to a Net Internal Area (NIA) convention, were converted to Gross Internal Area (GIA). The consumption was recalculated, but the NIA to GIA procedure did not greatly increase the floorspace, or the total consumption, due to the high percentage of the City's premises measured to GIA.

The final stages of the methodology of Chapter 4 generated profiles of appliance electricity consumption (and thereby internal gains), according to the End Use and Used For group of the appliances inferred, from the SHU analyses, to be present in the Line Entries of the SMV.

The results generated by the methodology laid out in Chapter 4 are described and discussed in Chapter 5.

Chapter 5: Results and Discussion

This chapter lays out the overall results of the research and discusses aspects of both the results and the application of the research method. A scenario of how the method might form part of an evaluation of energy conservation intervention policies is also described.

5.1 The Effect of Filtering the VOA Data and Applying the Line Description Identification and Area Capture Procedure

Figure 5.1, below, shows how the filtering of the VOA data, to eliminate duplication of records, reduces the initially-apparent number of premises, Line Entries and recorded areas of the Rating List and SMV databases. The lowest value of charts A, B and C are taken as the starting point for the application of the Line Description Identification and Area Capture Procedure described in Section 4.6.3. The figure shows how, without filtering, the number of premises, Line Entries and especially rateable area would be overestimated. Notably, the floor area would be over-estimated by 2.855 million m^2. Using the sum of Line Entry areas, as opposed to the premises Total Area field of the SMV, further reduces the rateable area by 110,000m^2. Note that the number of Line Entries (Lines) is not shown on the *x* axis of chart A, as the Rating List contains no Line Entries.

The general trend of the charts in Figure 5.1, is a large initial reduction in the number of premises and recorded areas, followed by smaller reductions.

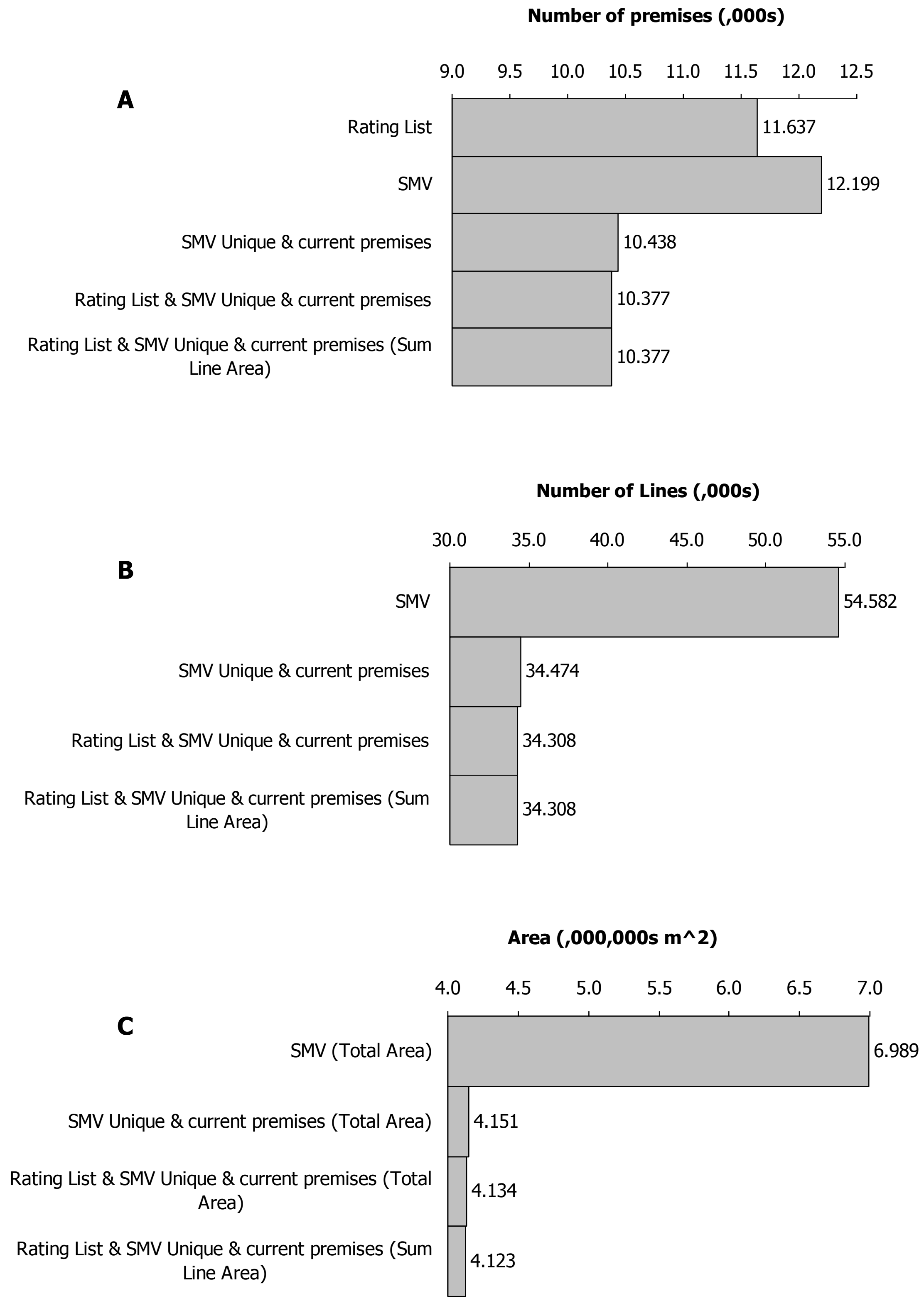

Figure 5.1: Reduction of number of premises, Line Entries and recorded area, at points in the VOA data filtering process.

The top line on the *x* axis of Figure 5.2, below, shows the effect of removing Advertising Concessions (PD code CA), from the filtered Rating List and SMV databases. Charts A, B and C show the effect on the number of premises, Line Entries and total recorded area, respectively. The middle line of each *x* axis shows the result of the allocation of Line Entries to Locations, i.e. "internal, "external", "internal/external", "unknown" and "not allocated". The bottom line of each chart shows the effect of Line Entries being allocated as "internal" spaces and thus likely to be subject to internal gains from electrical appliances.

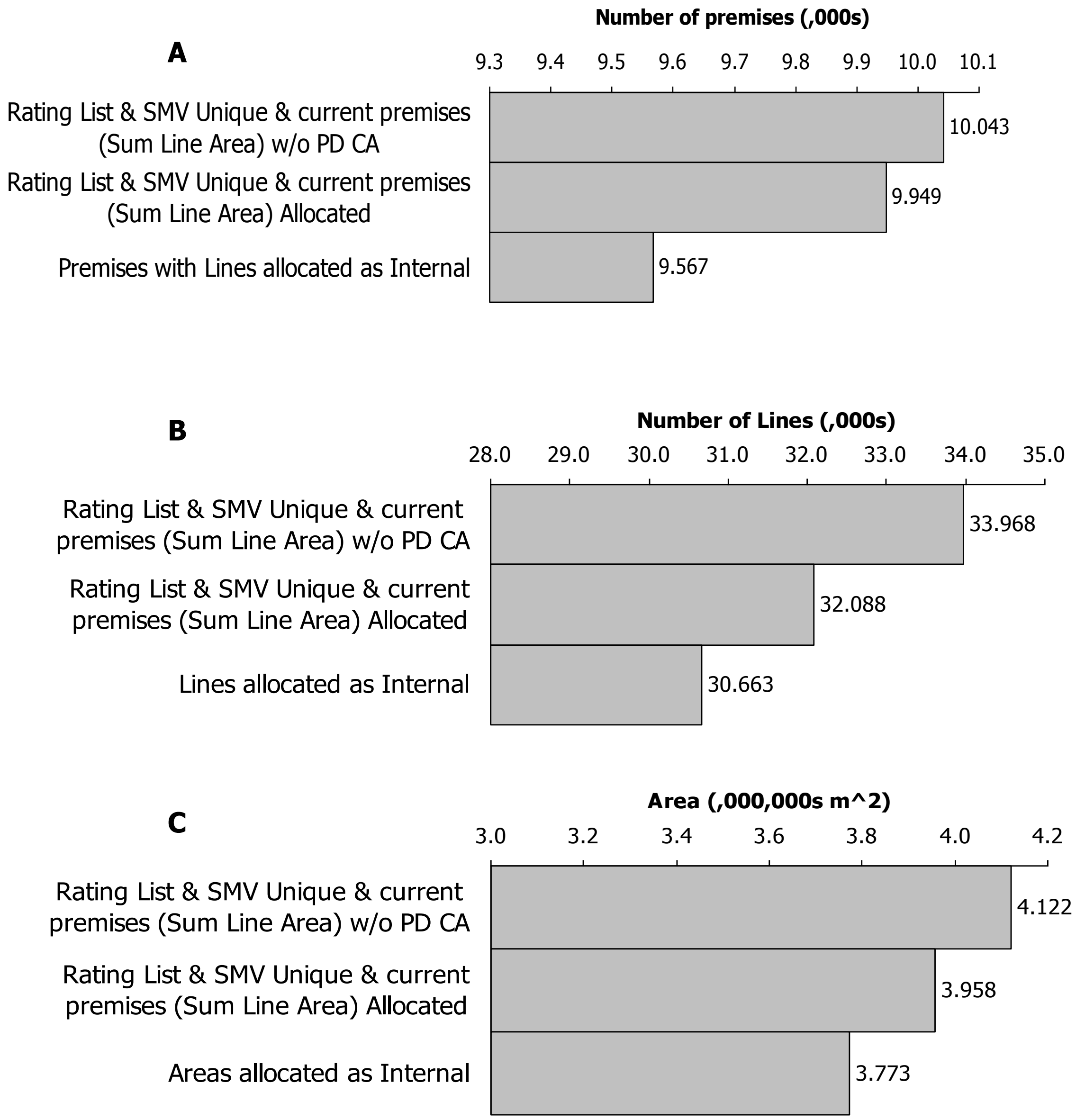

Figure 5.2: Reduction of number of premises, Line Entries and recorded area, at points in the Line Description Identification and Area Capture Procedures.

Below, Figure 5.3, shows how the number of premises, Line Entries, and total floorspace were affected by inferring the areas of the non-core activity support spaces (i.e. toilets and plant rooms etc). The effect of the conversion of some Line Entry areas, as described in Section 4.7.3, is shown in the bottom line of the *x* axis in chart C.

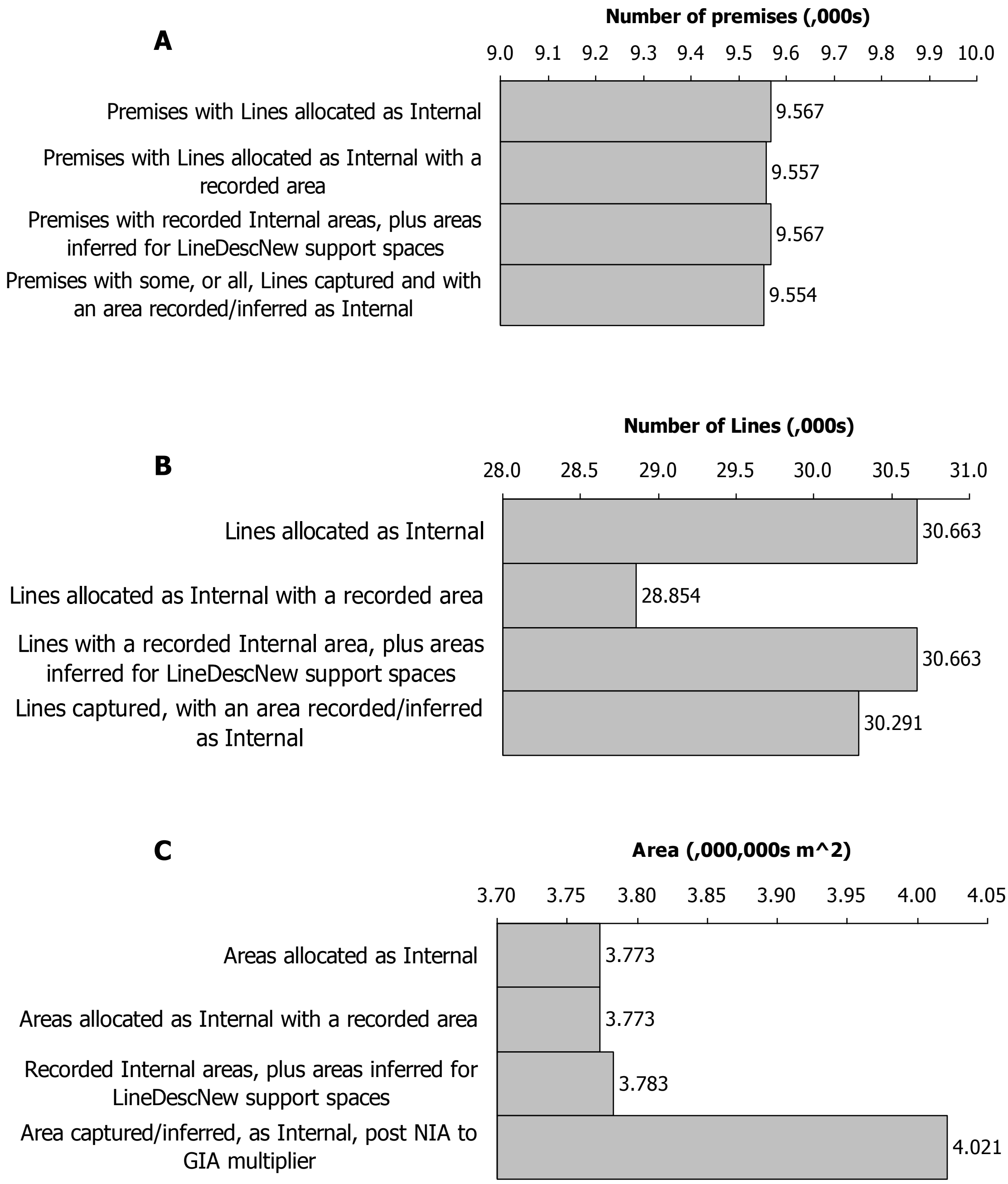

Figure 5.3: The effect on the number of premises, Line Entries and floorspace area, of inferring support space areas and implementation of the NIA:GIA multiplier.

Figure 5.3 shows that once the VOA data have been filtered to leave only premises that contain Line Entries identified and allocated as being internal, there is little further reduction in the number of premises and that 99.86% of these premises can have internal gains estimated for some or all of their floorspace. The sum of Line Entry areas, 4.123 million m^2 in the filtered SMV, shown in chart C of Figure 5.1 includes external spaces and premises Line Entry areas of a notional $1m^2$ (e.g. car parking spaces and advertising concessions). Removing all the non-internal Line Entries gives a total internal floorspace area of 3.773 million m^2, which indicates that $349{,}000m^2$ of the area recorded in the SMV are external, or not readily classifiable as internal. Excluding this area means that this research's method is applied to 91.5% of the known floorspace recorded in the SMV database of the test urban area, Leicester City.

5.2 Use of Floorspace in Leicester City

Non-domestic building stock models generally describe the stock being modelled according to each of the overall activities of the premises within the model's system boundary. In this research, the system boundary is the stock of non-domestic premises within the City of Leicester Billing Authority district. This research has attempted to disaggregate the floorspace of premises described by the Leicester City SMV, to give an alternative method of calculating the electricity consumption of appliances in internal spaces and hence their electricity-based internal gains. A key aspect in achieving this is determining how space is used inside the premises that constitute the non-domestic stock of Leicester City.

How the internal floorspace, identified and captured from the Leicester City SMV data (Section 4.6.3), is distributed across VOA Primary Descriptions is shown in Figure 5.4, below. It can be seen that slightly less than a third of this floor area is Factory floorspace (PD code IF, 32%), followed by Warehouses (CW, 20%), Shops (CS, 15%), Offices (CO, 13%), Workshops (IF3, 5%) and Retail Warehouses and Large Foodstores (CS10, 2%). Each of the remaining classes represents approximately 1% of the total. The "VARIOUS" category contains all premises types with less than 1% of the total captured floorspace.

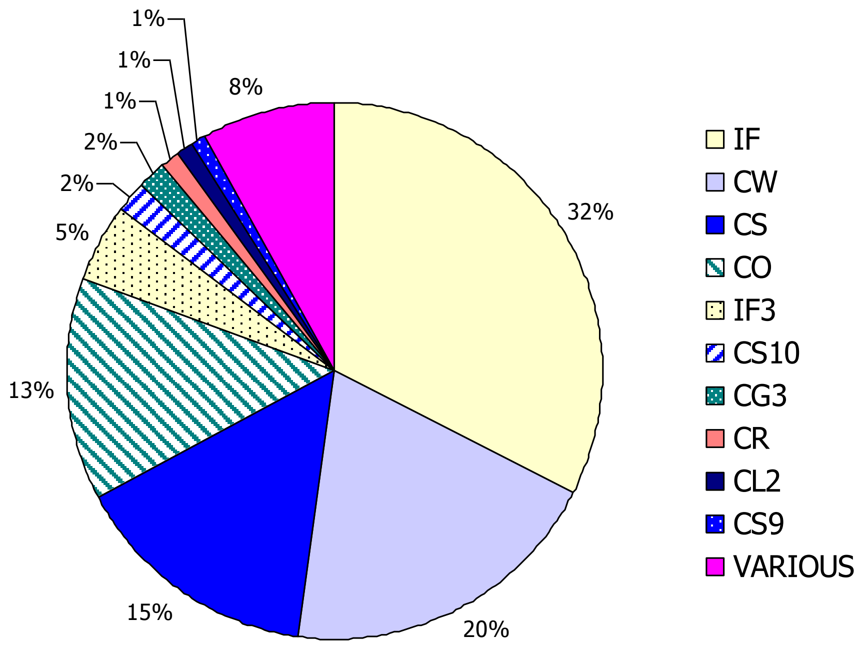

Figure 5.4: Distribution of internal floorspace per Primary Description in Leicester City SMV.

To gain a better understanding of the building stock, this research uses the detail of the VOA valuation surveys to go inside the premises listed in the Leicester City SMV, to analyse their use of space. Figure 5.5 shows how space is used in 9,554 (82%) of Leicester City's non-domestic premises, as recorded in the Rating List.

In Figure 5.5, Line Descriptions (post-sorting into their New Line Descriptions) have been aggregated into groups of similar activities. The full list of aggregations can be found in Table Appendix H.3, in Appendix H. The boundaries imposed by premises type (Primary Description) are ignored, indicating that the greatest amount of space is used for "process/workshops", closely followed by "storage" areas and "office work, meetings, computing".

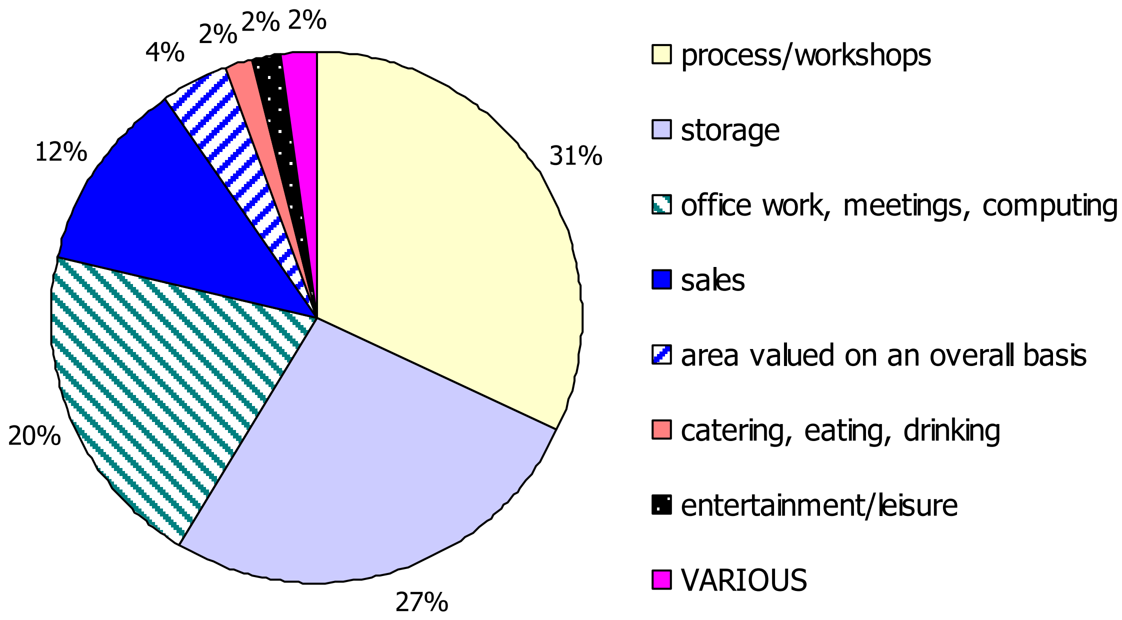

Figure 5.5: Total space use, by activity group, in Leicester City SMV premises.

The category "area valued on an overall basis" is essentially very large retail premises (some of PD code CS, plus CS10 and CS9) and some restaurants (PD code CR) that do not have their total area subdivided when surveyed and so these areas contain a multitude of activities. The floorspace of the 26 premises that are described in this way represents 24% of the total internal area of Leicester's shops (PD codes CS, CS9 and CS10). Slightly less than 6% of Restaurant floorspace is described in this way.

Figure 5.6 displays the area devoted to each of the activity groups, per Primary Description code, and shows how premises types can be dominated by particular activity types. However, this figure does not tell the whole story of how space is used and needs further analysis, especially when considering how space use in Leicester compares with the SHU survey samples.

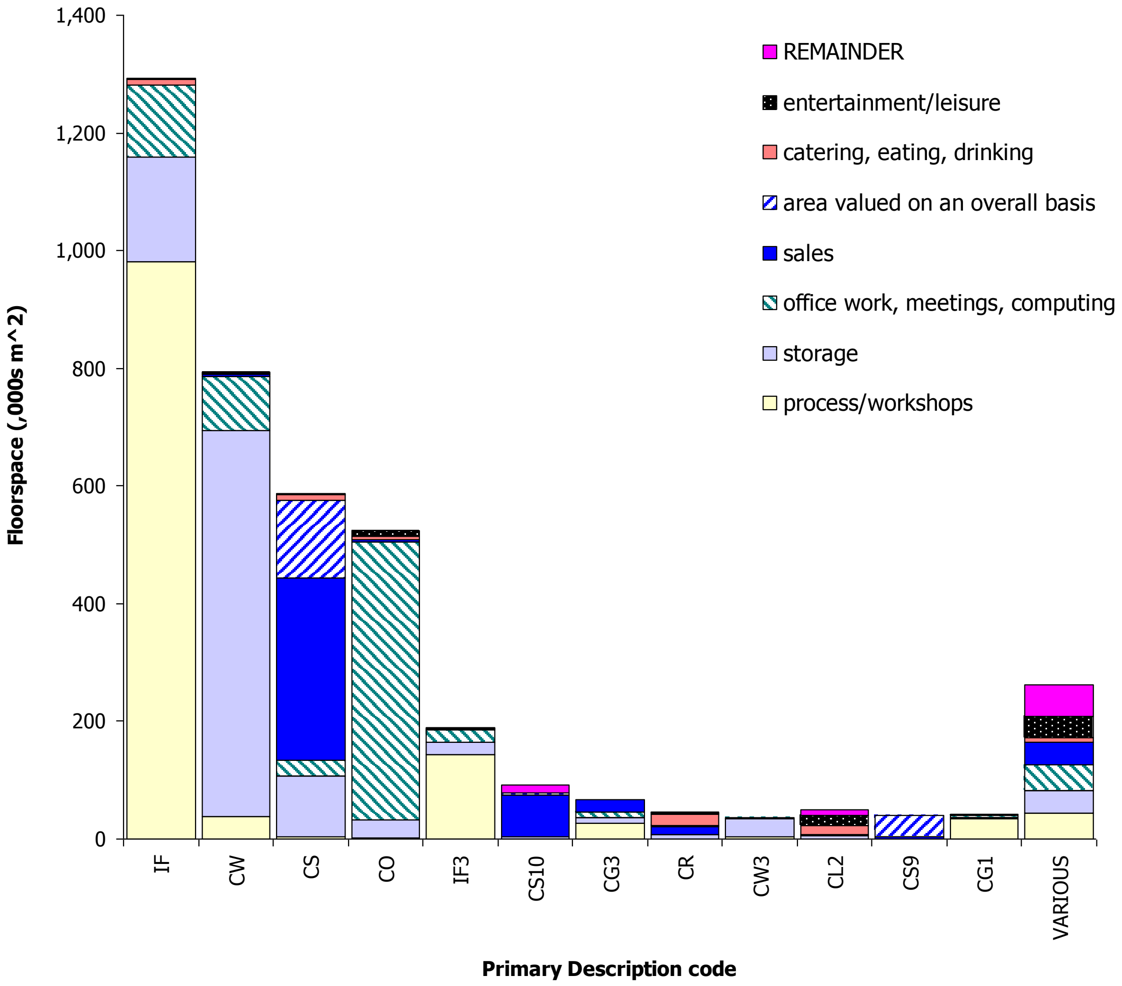

Figure 5.6: Breakdown of space use in Leicester premises, by PD code and activity group.

An exact comparison between the use of floorspace in the SHU survey premises and the premises listed in the Leicester City SMV is not fully achievable. This is caused primarily by three situations. Firstly, there is not a perfect match between the SHU Room Uses and the VOA Line Descriptions, even after the latter are rationalised, as described in Section 4.6. Secondly, a significant number of New Line Descriptions (LineDescNew), created by the SMV rationalisation method, are amalgams of SHU Room Uses. Thirdly, where data within the SHU samples do not exist for a particular VOA PD code and Line Description combination, Room Uses from alternative SHU PD codes have been used as a reasonable substitute to provide the basis of the appliance energy consumption in the LineDescNew (see Appendix I).

This third factor affects only relatively small areas within the Leicester City SMV and can be expected to apply in general to VOA datasets for England and Wales, due to the bulk of premises requiring the use of Accommodation Use Codes to describe activity areas in premises. So, although there are premises types and Line Description combinations that cannot be matched directly to SHU PD code and Room Use combinations, these are likely to constitute only small portions of the total UK stock.

The VOA data tend to fall into a limited number of Line Descriptions, within each PD class, due to the survey methodology adopted by the VOA. A principal reason for this is that the use of the Net Internal Area (NIA) measurement convention, masks a number of activity area types that are identified separately in the SHU surveys. The VOA Line Descriptions also, on the whole, make no distinction between, say, a general office, an office used for graphics work and an area used as a print room; whereas the SHU methodology makes such distinctions. On the other hand, the SHU methodology makes no distinction between an "office", "works office" and "ancillary office", where the VOA makes these distinctions.

In spite of these constraints, it is possible to provide a reasonable comparison of the use of space in the VOA and SHU datasets. However, this must come with the caveat that there is a certain degree of circularity in the disaggregation process, due to the use of multiple SHU Room Uses, applied according to their proportions within the SHU data. It may be said that the simple VOA Line Descriptions (and subsequent LineDescNew) are unpacked according to the combinations of Room Uses attributed to them from the SHU analyses, hence the degree of circularity. The effect of this is that the descriptions of spaces are more likely to align, but the corresponding floor areas are still the areas attributed to the Line Entry (in the SMV) or the Room (in the SHU).

As with the analysis of space use in the SHU data, three premises types will be analysed here: Shops, Offices and Factories.

Figure 5.7 shows the breakdown of how space is used in Shop premises in the Leicester City SMV data. The figure identifies space according to the activity groups (described above), to allow comparison with the SHU premises sample. Activity groups constituting less than 1% of the total captured SMV floorspace, have been amalgamated into the classification "VARIOUS". The data on which this figure is based do not include the Line Description "All Main Areas", as it does not give a useful description of the floorspace and because the generic profile of space use in Shops has been applied to it, at the SHU:VOA mapping stage of the methodology. Analysing this particular classification of space use would be completely circular and would say little about the use of space within Shops, in Leicester.

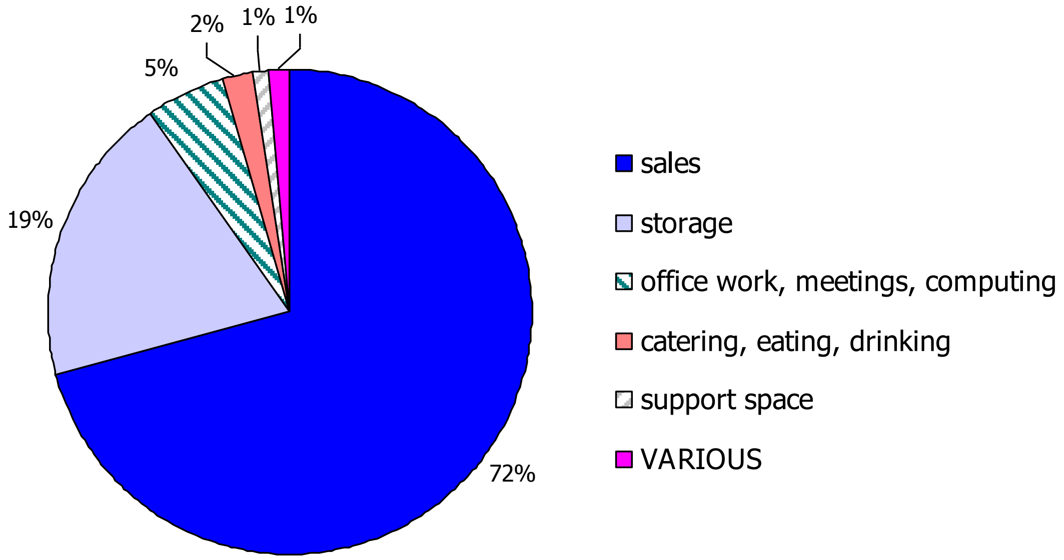

Figure 5.7: Total space use in Shops, by activity group, in Leicester SMV.

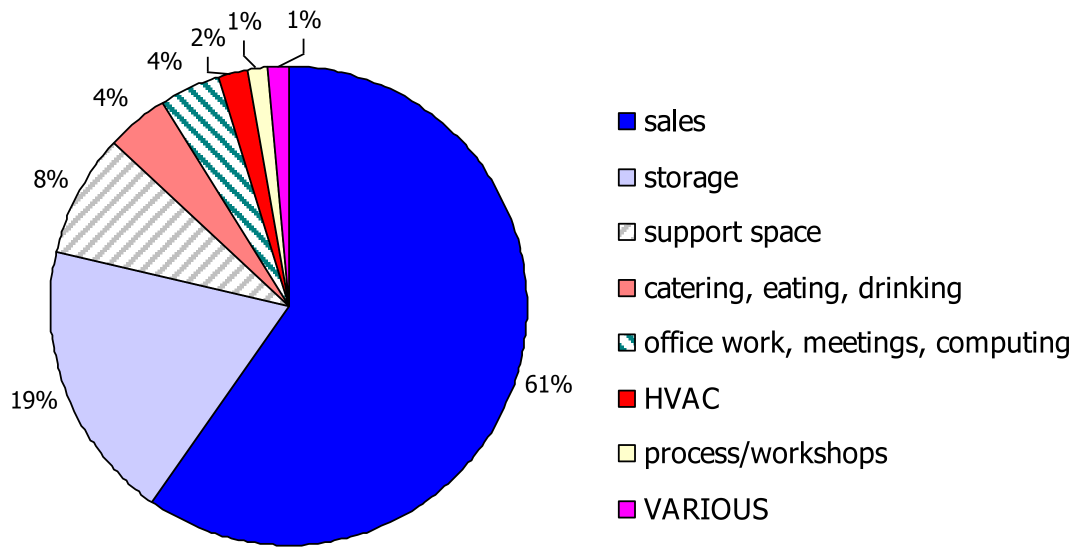

Figure 5.8: Total space use, by activity group, in SHU Shop premises sample.

Comparing Figure 5.7 with the SHU space use profile in Figure 5.8 does not present a convincing argument that space in Leicester's Shops is used in the same way as in the SHU Shops sample. However, only SMV Shop premises with the Line Description (or LineDescNew) "All Main Areas" are affected by the SHU profile, as all other Shops in the SMV are assessed according to their individual Line Entries, as shown in Figure 5.7. The suggestion is that due to some premises having Line Entries for only sales-type spaces, there is a much higher proportion of sales space in the Leicester data than in the SHU sample.

The sales areas predominate, in the SMV, but the proportion of storage space is also significant and identical, between the Leicester and SHU sample premises. This is unexpected, as the VOA area measurement convention, for Net Internal Area, would exclude small many small storage spaces, as not being of value to the occupant. This is born out by the SMV datasets, where there are many instances of "internal storage" that are not valued. So, realistically, the Leicester data ought to contain a lower percentage of storage space than the SHU sample. However, as the unvalued areas are likely to be small, the overall difference would be small.

Office work areas are also broadly similar. The "VARIOUS" classification contains all space uses that constitute less than 1% of the total floorspace. The support space is considerably larger, in the SHU sample, due to the NIA convention not measuring some circulation spaces and no stairwells. Depending upon the application of the description "circulation" space in the SHU surveys, some of the difference in the sales areas, between the Leicester SMV and SHU sample, may be accounted for by circulation space not being specifically identified as such in the Leicester data. Also, some of the HVAC areas of the SHU sample would not appear in the Leicester SMV, as they are not generally rateable. Even though some plant rooms will have had their floor areas inferred by this research's methodology (section 4.7.2.1, page145), it is likely that there will still be a number of such spaces that have not been recorded by the VOA surveyors, or have evaded the area inference method, due to non-standard Line Descriptions.

The profile of space use in Office premises, in Leicester (Figure 5.9, below), shows that 88% of the area is used for office work, whereas the SHU sample's proportion is 70% (Figure 5.10). This is a large difference and may be due, in part, to the VOA including some circulation space in the NIA measurement convention (i.e. areas between individual rooms or floors, but not within unrated common areas). However, less than 3% of the SHU Office premises sample's total floor area is recorded as "circulation".

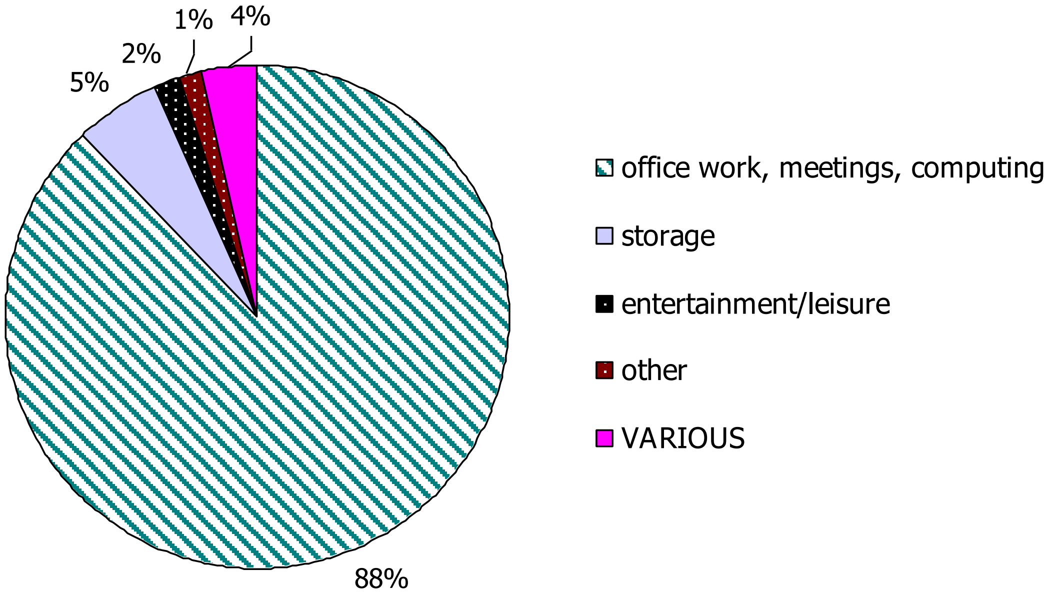

Figure 5.9: Total space use in Office premises, by activity group, in Leicester SMV.

The inclusion of the activity group "entertainment/leisure" appears anomalous, but in fact highlights a finding of the research. Scrutiny of the Leicester VOA SMV Line Entries has revealed that there are a number of Line Descriptions that describe activities that would not normally be associated with the Primary Description code used to classify the premises. Examples, within the office premises include "fitness", "gymnasium" and "dance school". A possible explanation is that the premises have undergone a change of use, from offices, to another completely different activity. If this is the case, the PD code may not be as accurate an indicator of the premises' activity as the Line Descriptions. For example, the three Office premises, in which the Line Description "gymnasium" appears, have a minimum of 83% of their floorspace designated this way, so the premises can be classed as gymnasiums (entertainment/leisure) rather than Offices.

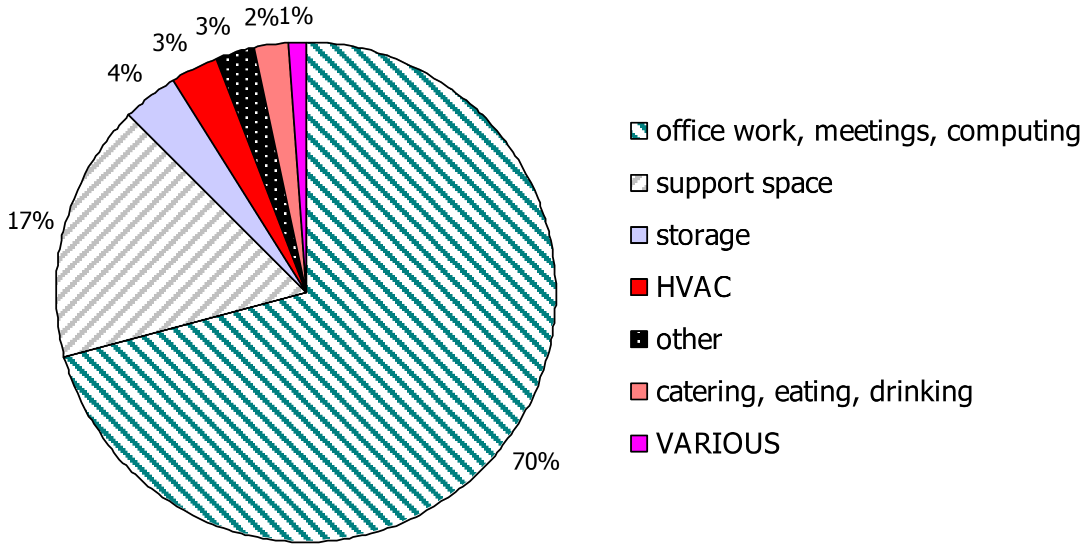

Figure 5.10: Total space use, by activity group, in SHU Office premises sample.

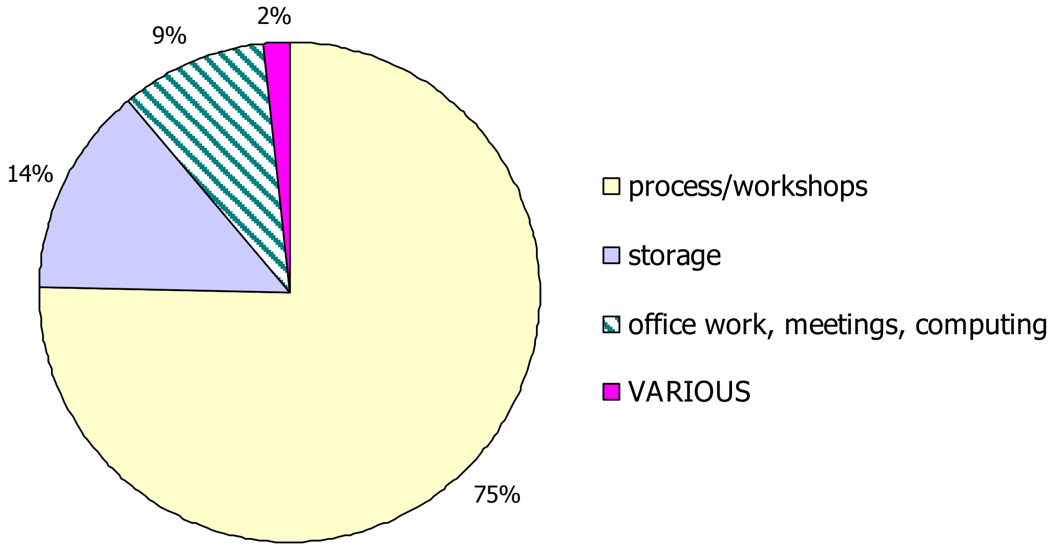

Figure 5.11: Total space use in Factory premises, by activity group, in Leicester SMV.

In the profile of space use in Leicester Factories, shown in Figure 5.11, the proportion of area allocated to storage activities and office-type activities are the same as those shown in Figure 5.12, for the SHU Factories sample. However, 10% more of the total area is given over to process/workshops in the Leicester Factories, than in the SHU sample. This could have a marked effect upon stock energy modelling, especially when using a whole premises-based method, due to 32% of Leicester's captured SMV area being classed as Factories.

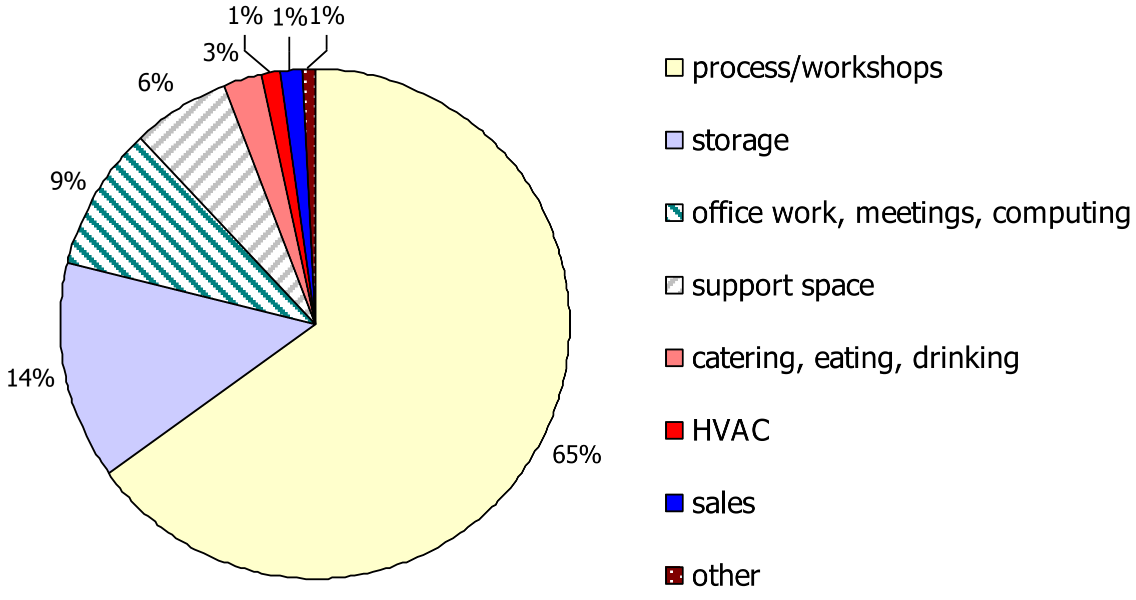

Figure 5.12: Total space use, by activity group, in SHU Factory premises sample.

Setting aside the use of electricity and focussing on the effects of internal gains, calculating HVAC loads would be affected by a 10% difference in the area attributed to process/workshop, due to this floorspace being likely to have a different net heating/cooling requirement to the rest of the premises' floor area.

These analyses of space use, in the test urban area (City of Leicester), demonstrate how divining the descriptions of Line Entries can be used to reveal the activities being performed in subdivisions of premises. The homogenisation of premises is avoided and it becomes possible to infer appliance electricity consumption in the divisions of activities that occur withinin the premises of the non-domestic building stock. As with the classification of built form devised by Steadman et al (2000a), the use of space within premises can be disaggregated into a limited number of individual activities and reassembled into premises and the stock. Further research, based on increased numbers of detailed survey data, may eliminate premises as an activity group.

5.3 Estimate of Appliance Electricity Consumption and Internal Gains for Leicester City Non-domestic Premises

Using the method described in Chapter 4, the electricity consumption of appliances in Leicester City, is estimated to be 788,658 MWh, for the year 2008. Figure 5.13, below, shows how the electricity consumption is divided across the major Primary Description classes, in the Leicester SMV premises. Where a Primary Description class' total consumption is less than 1% of the sum of all classes, it has been aggregated into the "VARIOUS" category, which contains 31 Primary Description classes.

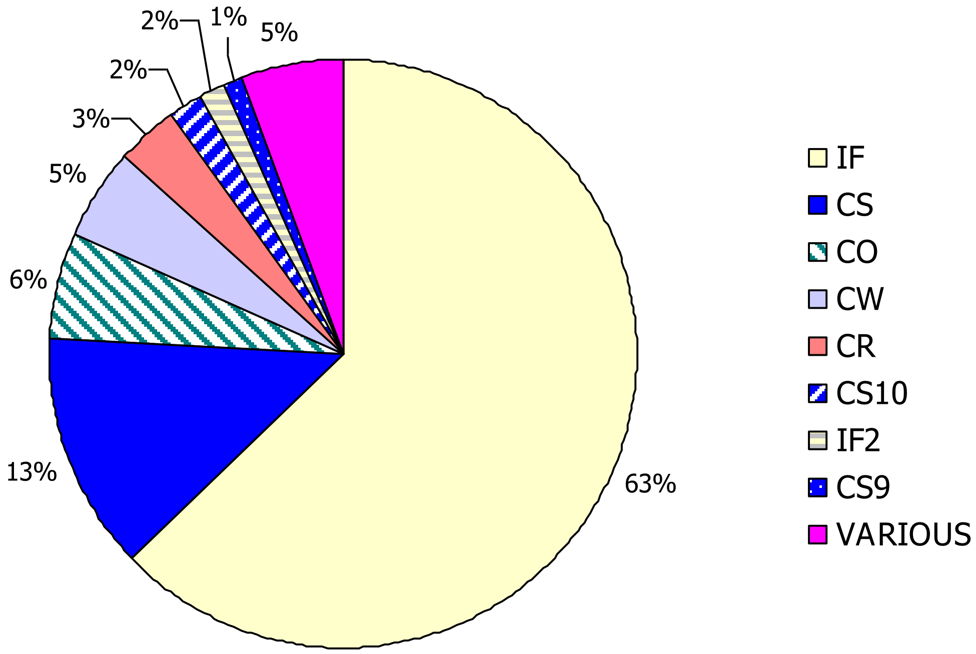

Figure 5.13: Leicester City's total appliance electricity consumption per Primary Description class.

This result indicates that Factories (PD code IF) are the dominant users of appliance electricity, when process electricity consumption is included. Considering the extent of floorspace in Factories (Figure 5.4, above), this is reasonable. The three next greatest consumers are Shops (13%), Offices (6%) and Warehouses (5%).

5.4 Comparison of Estimated Consumption against Measured Consumption

The Department of Energy and Climate Change (DECC) provides information on the energy consumption of both domestic and non-domestic premises, in England, Wales and Scotland, at varying levels of aggregation. Table 5.1 gives the total non-domestic electricity consumption of Leicester City and the numbers of billing meters. It may be seen that electricity flowing through half-hourly meters accounts for almost three quarters of the total electrical consumption but that this meter type constitutes only 6% of all non-domestic meters. This indicates that the bulk of electricity consumption goes to a relatively small number of sites, with heavy usage.

Table 5.1: Annual electricity consumption and numbers of billing meters for the Leicester City local authority area, for year 2008.

	Consumption (MWh/year)	Number of meters	Percentage of total consumption	Percentage of meters
Half hourly meters	775,154	784	74	6
Non-half hourly meters	272,835	11,434	26	94
Total	1,047,989	12,218	100	100

Source: (DECC, 2010b)

There are 11,634 premises in the Leicester City Rating List. Some premises are very likely to be made up of a number of buildings, with one, or more meters and some meters will be measuring the consumption of multiple buildings, or multiple premises. In view of this, there is an approximate correlation of the number of premises and the number of billing meters. It should also be remembered that there will also be a small number of premises that are not recorded in the Rating List.

Due to concerns over commercial sensitivity, DECC aggregates the City's half-hourly metered consumption into a single number for the annual consumption, whilst the non-half-hourly consumption is accessible at the Middle Layer Super Output Area *(MLSOA) level (DECC, 2011b). A consequence of this is that non-domestic electricity consumption through half-hourly meters cannot be accurately assigned to each of the

* A statistical area developed by the Office for National Statistics, roughly equating to an area containing a mean of 7,000 residents (OFFICE FOR NATIONAL STATISTICS (2011) Information Note: Super Output Areas.

36 MLSOAs in the Leicester City local authority area. However, the total consumption figure, released by DECC, does provide a yardstick to which this research's results may be compared.

This research calculates the electricity consumption of appliances in the non-domestic sector, of the City of Leicester, to be 788,134 MWh, in 2008. This represents 75.2% of the City's total electrical consumption by this sector, as recorded by DECC. Considering the method is primarily to calculate internal gains resulting from appliance use, therefore excluding electricity used in providing heat and coolth in HVAC systems, the calculated value is acceptable. However, there are a number of elements of the research that need to be taken into consideration and may be seen as caveats.

Firstly, the method does not include premises that do not appear in the Rating List database, so the calculated electricity consumption does not, for the most part, include some consumers such as places of worship and Crown properties. Secondly, significant premises types such as schools, universities, hospitals, hotels and public houses appear in the Rating List, but are missing from the SMV database so these still need to be accounted for. Thirdly, the method does not identify all the Line Descriptions in the SMV and therefore does not capture all of the corresponding floor area, upon which consumption calculations are based (see Section 5.1).

5.5 End Uses of Appliance Electricity Consumption

The usefulness of the calculated appliance consumption is improved by disaggregating the modelled consumption and understanding which activities are causing the consumption and where these activities occur. By analysing the outputs of the research, it is possible to associate the consumption recorded by the DECC (Section 5.4) with End Uses. Analysis of these inferences can be carried out at the stock, premises and Line Entry level, for the Leicester SMV database.

5.5.1 Consumption According to End Use

Below, is a simple disaggregation of the calculated electrical appliance consumption of Leicester City into End Uses. The consumption is split between fourteen End Uses, but is dominated by "process" (62%), with the bulk of the balance being split between just four significant uses: "light"; "catering"; "computer"; "small power". The "REMAINDER" category contains all other End Uses that constitute less than 1% of the total consumption.

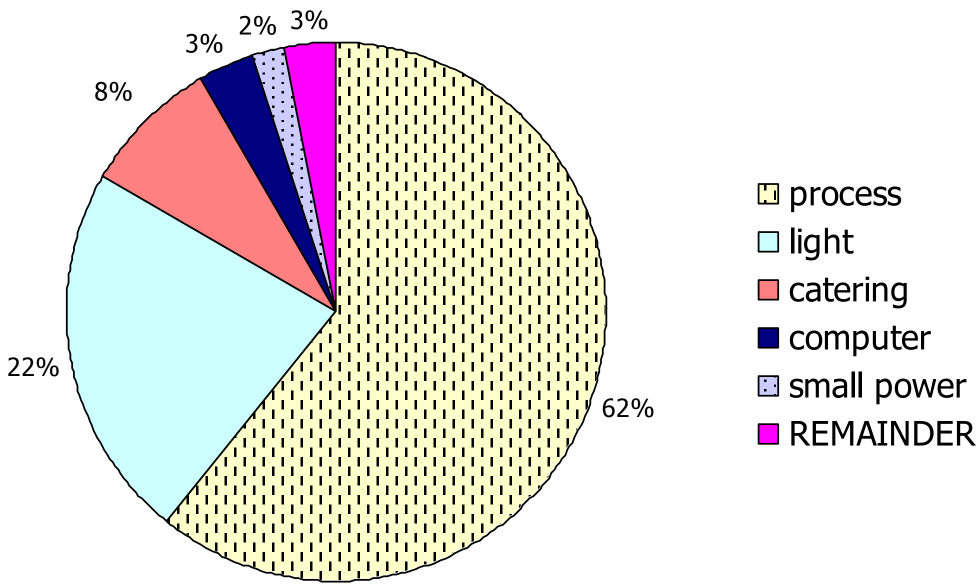

Figure 5.14: Leicester City total appliance electricity consumption, by End Use.

This overall picture of consumption can be interrogated further to show which premises types are consuming the electricity and how much is being consumed by each End Use. This disaggregation can be seen in Figure 5.15.

Including the consumption of electrical process energy, calculated at the individual Line Entry level, is a departure from previous methods that estimate process energy (usually including all other fuel types) at the premises level. It is likely that the Energy Intensity of process areas will vary considerably, according to the nature of the industrial process being carried out. However, across the large floor areas of the non-domestic stock, an average value for Energy Intensity may still be representative. If this is the case, then the profile of appliance electricity consumption, and hence internal gains, depicted for Leicester in Figure 5.15, suggests that there should be a reduced requirement for heating these process areas in Factory premises, compared to similar floor areas used for less energy intensive activities.

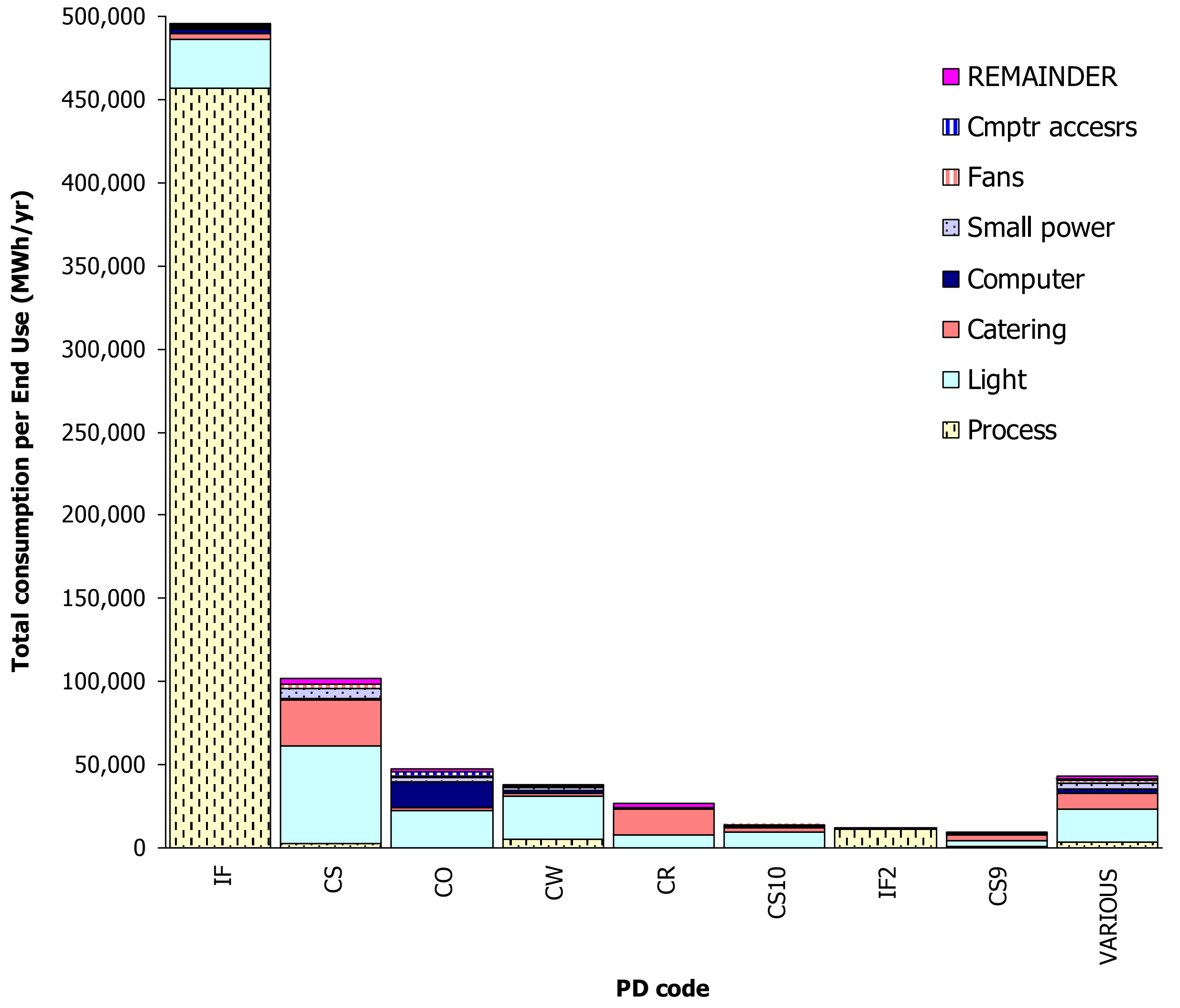

Figure 5.15: Leicester City appliance electricity consumption, per PD code and End Use.

The limitation that must be indicated here, though, is that the analyses of Factory premises in the SHU data are subject to a very small sample size (just five premises), so the true range and mean of the Energy Intensities of Factory process areas may not have been accurately captured by the SHU energy surveys. Certainly, an improved sample size, taken across a number of different industrial processes, would create greater robustness in the prediction of electricity consumption of process areas and their internal gains. Analysis according to a combination of Standard Industrial Class (SIC) and Primary Description might provide greater detail, but would most likely require a considerably larger survey sample. And, at the resolution of modelling thousands of premises, the SIC subdivisions may prove to be of less value.

As this research's method uses VOA descriptions of premises and floorspace, details of the nature of processes cannot be known in detail, or with certainty, from the VOA datasets, making detailed subdivision of process energy less applicable.

Setting aside the electricity consumption of process appliances, the consumption of activities more generally associated with the operation of buildings can be estimated.

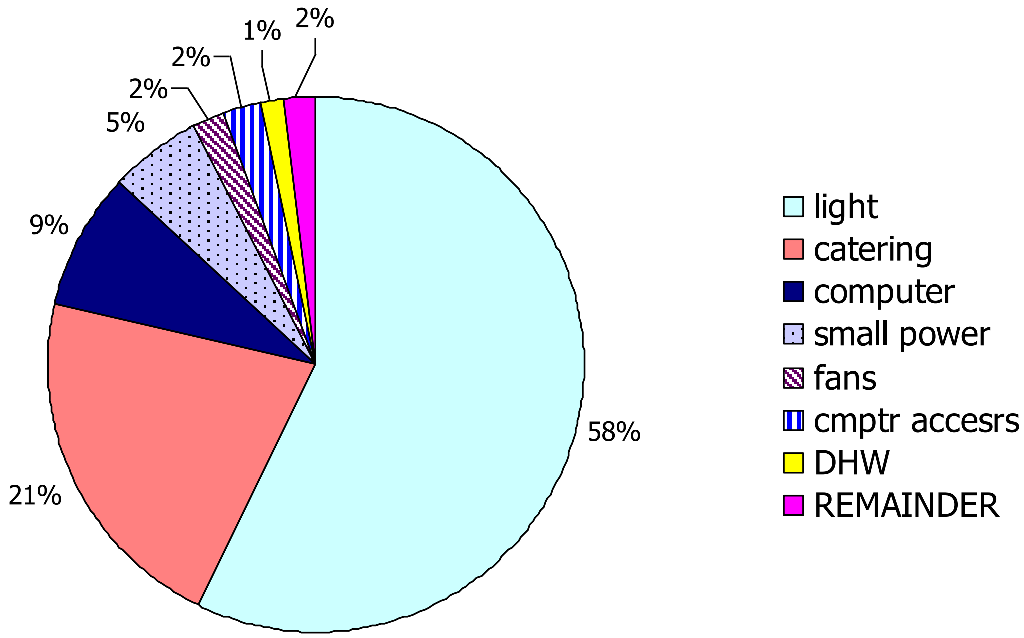

Figure 5.16: Distribution of total appliance electricity consumption, in Leicester, per End Use, excluding "process" consumption.

In Figure 5.16, light has become the dominant End Use. This is most likely due to most internal spaces requiring some degree of lighting, coupled to Leicester having 15% of its internal floorspace located in Shops (Figure 5.4), which have high Energy Intensities for the lighting End Use.

The profile of End Uses has been unpacked in Figure 5.17, where it can be seen how Factory premises (PD code IF) have moved down the consumption ranking, to become the third-largest consumer; however they still use a lot of energy for lighting. The large area of Warehouse (CW) floorspace can also be seen to be contributing to the significance of lighting. Shops (PD code CS) are now the foremost consumers, principally due to the levels of consumption for lighting and catering. This is interesting, as the high level of consumption for the "catering" End Use is influenced by chilled and frozen storage equipment, such as display fridges and freezers, being classed as "catering" equipment. This is even more pronounced in PD code CS9, Superstores. In reality, these types of appliance are for enabling the sale of chilled or frozen goods, so analysis according to the New Used For groups (see Section 3.10) can indicate the activity for which the appliances are used.

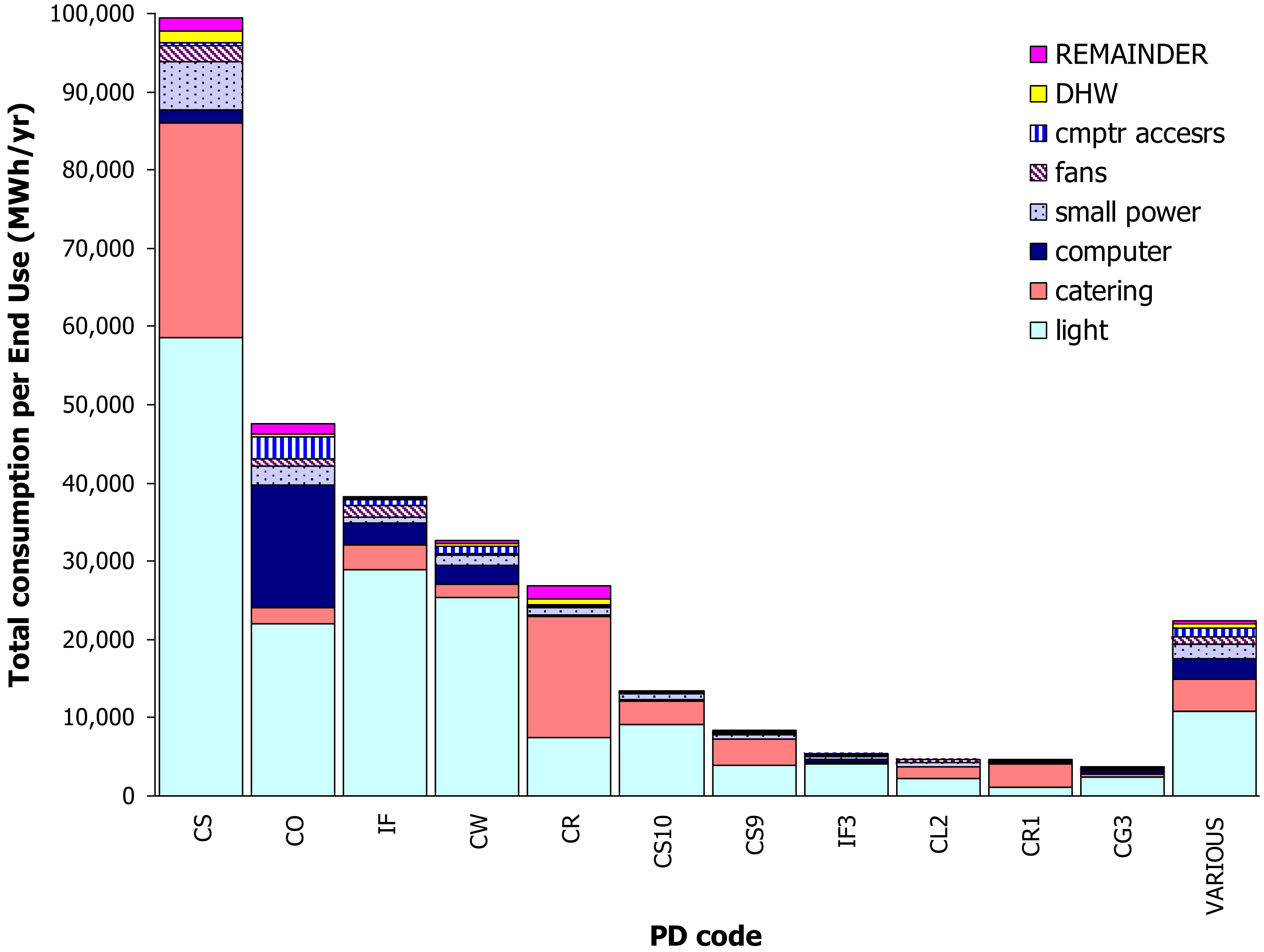

Figure 5.17: Total Leicester City appliance electricity consumption, per PD code and End Use, excluding "process" consumption.

5.5.2 Consumption According to Used For Group

This section investigates how the electricity consumption of Leicester's non-domestic stock can be analysed according to the activity it is used for. These analyses are based upon the Used For groups described in Section 3.10. Below, Figure 5.18 indicates how appliance electricity is distributed across the Used For groups, in the Leicester City SMV Line Entries that have been identified and captured.

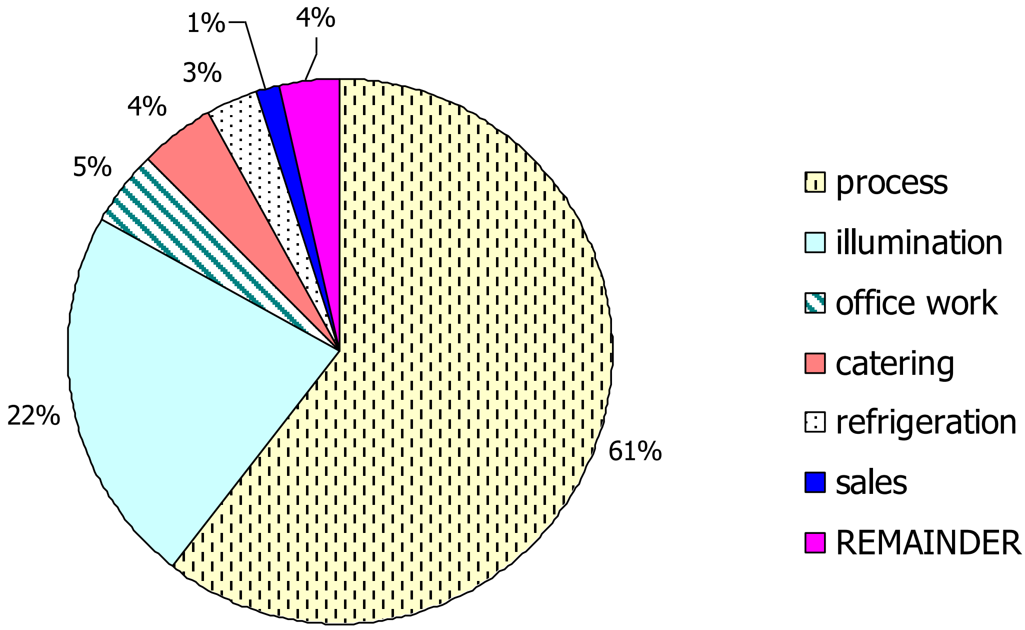

Figure 5.18: Total consumption by appliances in Leicester, per Used For group.

The distribution is broadly similar to the End Uses shown in Figure 5.14, but there are two notable exceptions to this. Firstly, the Used For group "office work" includes the End Uses "computing", "computer accessories" and some of the "small power" appliances. This gives an overall figure for the consumption attributable to the operation of office work activities, bearing-in-mind that this is for office work in all premises types. Secondly, the "catering" End Use has been separated into the "catering" and "refrigeration" Used For groups, leaving a 12% difference between the sum of "refrigeration" and "catering" in the Used For groups and "catering" End Use.

This separation highlights the importance of consumption used for refrigeration appliances that are not classed as being used for (the End Use) "cooling" the internal spaces of premises (in the SHU datasets). In fact, this Used For group mostly consists of appliances that are used for providing temperature controlled food storage. Figure 5.19, below, shows how the bulk of the consumption attributed to "refrigeration" is located in Shops. This helps explain why the level of consumption for the End Use "catering" is so high in the Shops analysis shown in Figure 5.15 and in Figure 5.17. It is not the amount of food preparation being carried out, but the number and power rating of refrigeration appliances that makes the major contribution to the "catering" End Use.

Also, within the SHU Shops sample premises, much of the refrigeration appliance consumption takes place in the building services spaces of larger premises. In the Leicester SMV, the Line Description "Plant room" tends to occur in the descriptions of larger premises, rather than in smaller shops, so the level of refrigeration consumption is also partly tied to the size of premises in the SMV. Consumption Used For refrigeration, occurring in the sales spaces of the SHU Shops sample, is placed into the sales spaces of the Shop premises in the SMV, as it should be.

The high level of consumption attributed to the "catering" Used For group, in Restaurants and Cafés (PD codes CR and CR1) is likely to be partly due to the nature of the SHU sample of Restaurants, as discussed in Section 3.9.

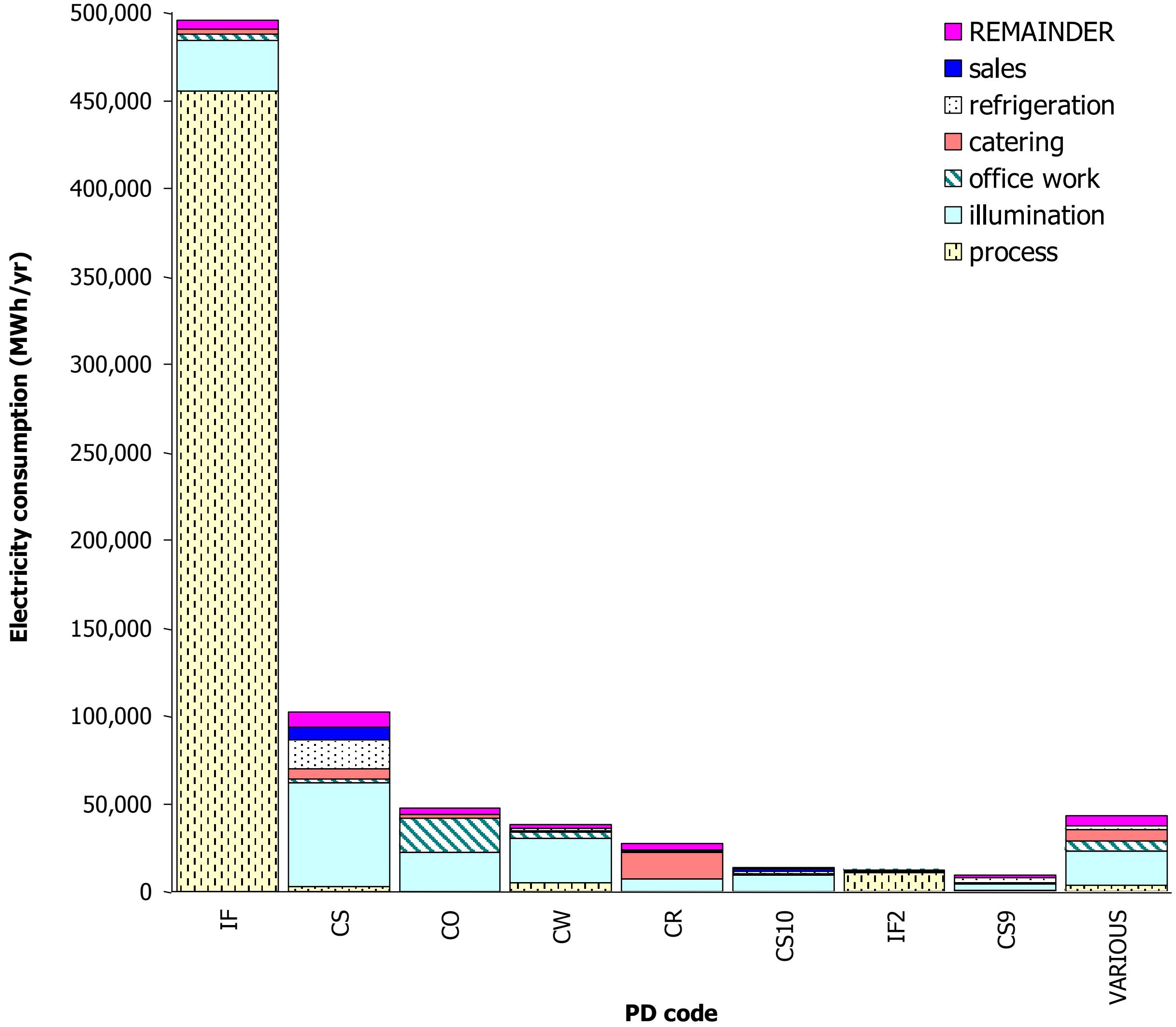

Figure 5.19: Total Leicester appliance consumption, by PD code, per Used For group.

The distribution of consumption within Used For groups, after the removal of "process", is shown in Figure 5.20, below. This analysis is included for the interest of those concerned with the energy benchmarking of premises and buildings, where energy consumption by processes is usually not assessed. Also, non-domestic building stock energy modelling usually excludes process energy consumption.

"Illumination" has become the dominant consumer, followed by "office work", "catering" and "refrigeration". When compared to Figure 5.16, the effect of identifying "refrigeration", upon the "catering" End Use category, can be seen to have split the latter into two groups. It may also be observed that the sum of "catering" and "refrigeration" Used For groups (11% + 8%) does not equal the "catering" End Use (21%). It is not apparent where the missing 2% has gone, but it must be contained within the other Used For groups, as the sums of End Use and Used For consumption are the same.

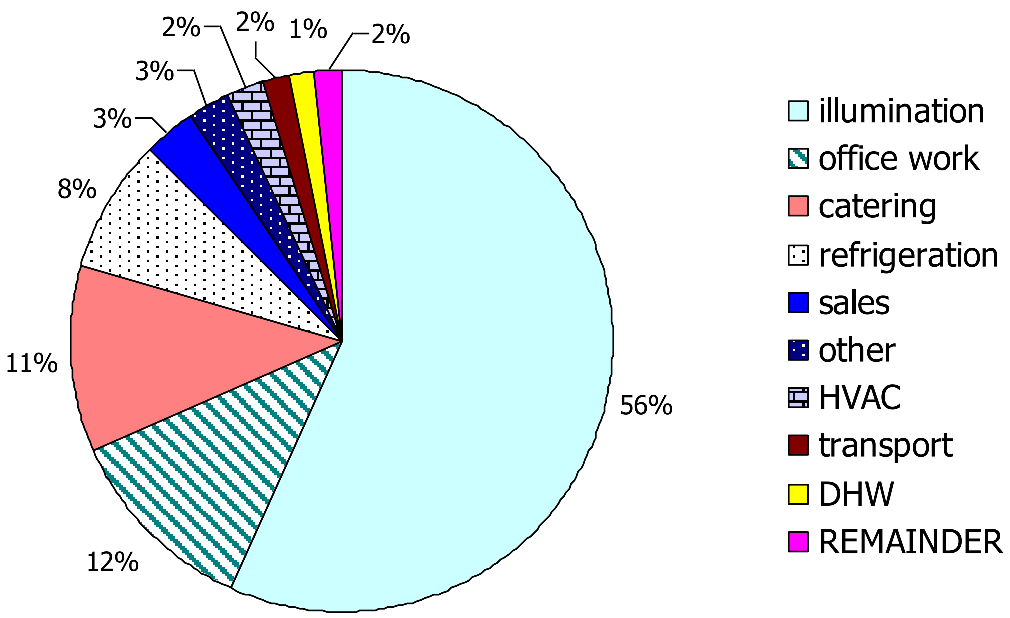

Figure 5.20: Total consumption by appliances, by Used For group, excluding "process" consumption.

The importance of "office work" consumption has grown to become the second largest Used For group, but it is still dwarfed by "illumination". This suggests that addressing the efficiency, and perhaps the level, of lighting in the non-domestic stock could be an effective means of reducing electricity consumption.

Figure 5.21, on the following page, shows the distribution of consumption across the major Primary Description classes, for each Used For group, excluding "process" appliance electricity. If "illumination" were chosen for improved efficiency, or conservation, Shops ought to be the prime target, followed by Factories, Warehouses and Offices.

The differences between Figure 5.19 and Figure 5.21 show the importance of "process" consumption, as a component of overall consumption. The comparison may also be used to indicate how the energy benchmarking of premises is affected by this "process" consumption. The bulk of process consumption takes place in Factory premises and can be seen as intrinsic to the activity within the premises. However, for the energy consumption benchmarking of Factory premises or factory buildings, this process consumption would be separated from other consumption and usually only the balance – the non-process consumption – would be assessed.

For premises types where it is assumed that core "process" loads do not exist – for example, Offices – the operation of the entire premises is assessed for benchmarking purposes. Yet it can be said that the core "process" activity of Office premises is "office work" and that all other consumption is secondary to this. So, there is an argument for applying a benchmark to the activity (or process) separately, because the activity affects the overall consumption of premises, through the premises' activity interacting with the building and its HVAC systems, through internal gains.

In terms of the energy consumption of activities, it is the equipment associated with the activity that is the ultimate consumer of energy. Built form, HVAC equipment and appliances may be associated with activities, but the purpose of HVAC equipment should be to provide an environment that is safe and conducive to the activity being performed in the treated space. This is why an agricultural hay barn often does not require any appliances: it is only necessary to provide an environment that is sufficiently dry and ventilated – which can usually be achieved through the use of an appropriate roof and walls. There are very few activities that do not have some form of associated appliance(s).

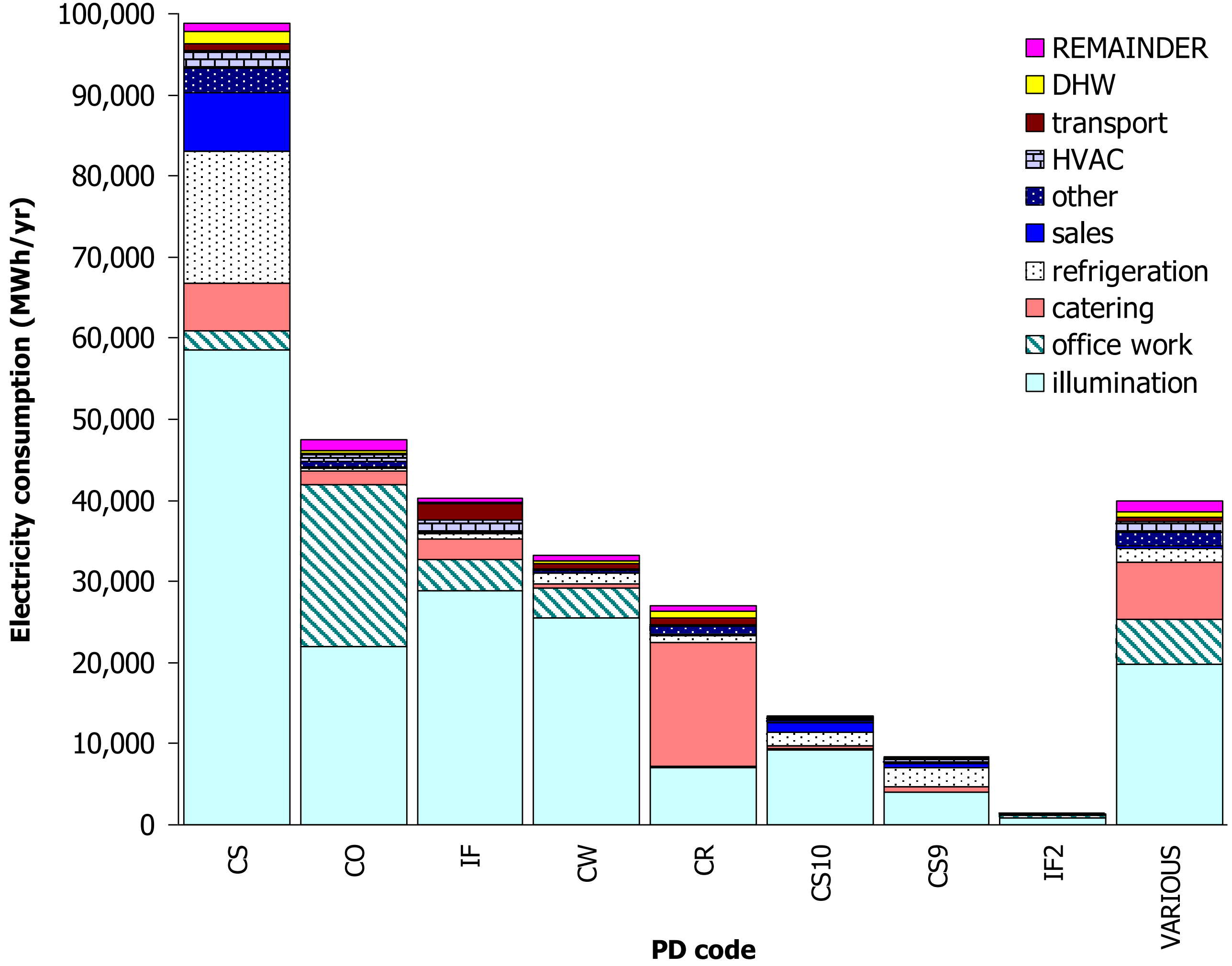

Figure 5.21: Total Leicester appliance consumption, by PD code, per Used For group, excluding "process" consumption.

Once an internal space contains an activity and associated appliances that result in internal gains, the interaction of built form, appliances and HVAC becomes more complicated. Altering the energy intensity of appliances and thus activities, can be expected to have an effect upon the HVAC system and its energy consumption. Similarly, when occupancy changes, this ought to have an effect on the internal gains resulting from the occupants but also the gains from the appliances they use.

The application of thermal performance standards to the fabric of buildings could, conceivably, have a negative effect on energy consumption in buildings containing certain activities. For example, industrial processes in Factory premises could cause very high internal gains. Stipulation that the buildings containing these activities should have highly-insulated fabric might result in increased consumption due to the need to cool the activity spaces. Therefore, effective energy consumption interventions require an understanding of activities and their associated appliances, in addition to an understanding of the built form and HVAC service systems of the buildings that house activities.

5.6 Modelling by Generic SHU Room Uses

To carry out further study of the method of applying Energy Intensities, derived from the SHU Room Uses, to individual Line Entries of the SMV datasets, generic values were applied to the SMV Line Entries. These generic values were calculated from the data across each Room Use, in the SHU datasets, regardless of Primary Description class. A new generic PD Code and Room Use SHU:VOA Map was created. This method is distinct from using generic values, based upon whole premises. The overall effect is to ignore Primary Descriptions and use the New Line Descriptions, only, to derive consumption for floorspace.

The results of this experiment delivered a total electricity consumption figure, for the Leicester SMV, of 811.2 GWh, which is 103% of the original calculated consumption using the more sophisticated non-generic PD code and Room Use SHU:VOA Map. Although the overall consumption figure is almost unchanged, the ranking of premises, according to consumption, has changed, with the Workshops class (IF3) moving up the ranking to become the third largest consumer. This is shown in Figure 5.22, below, which may be compared to Figure 5.13, on page 164.

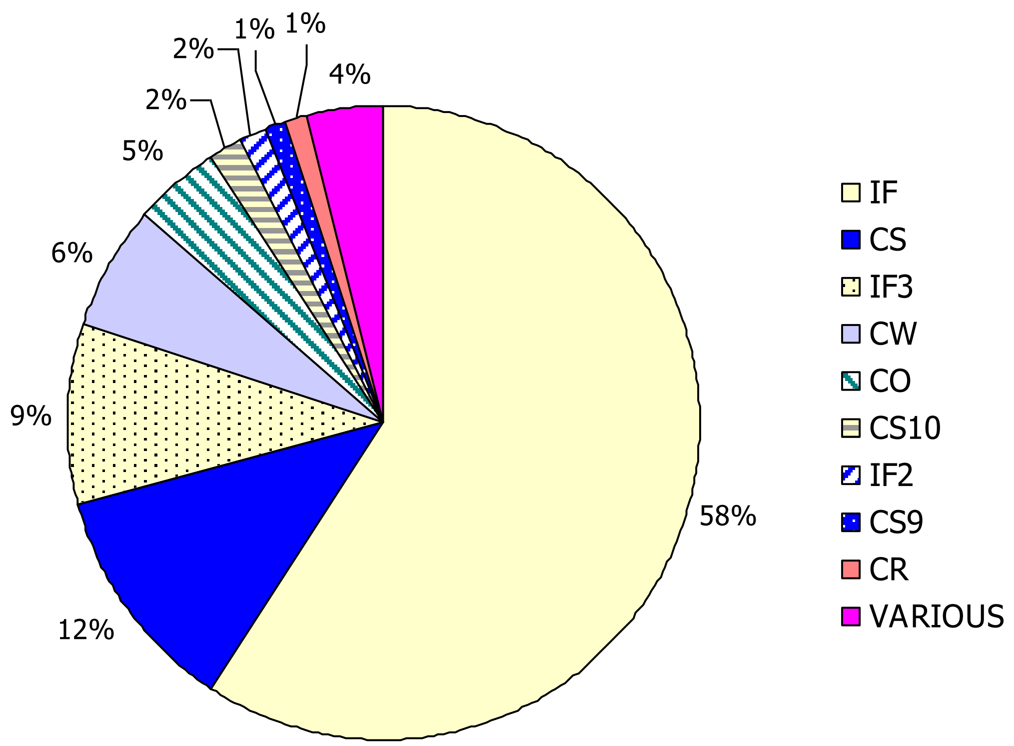

Figure 5.22: Leicester City's total appliance electricity consumption per Primary Description class, using generic Room Use Energy Intensities.

This new overall pattern of consumption can be explained by the profile of process consumption being affected by the high EI of the SHU Factory "process" Room Use and the relatively low EI of SHU Workshop "process" Room Use. The SHU Factory EI has effectively raised the EI of Workshops in the SMV, as the consumption of the Workshop Line Entries will be calculated from a higher mean EI, taken from across all SHU premises. This higher overall EI for the "process" End Use has also increased the Warehouse (CW) share of the consumption, whilst Shops (CS), Offices (CO) and Restaurants (CR) have all had their percentage of the total reduced.

The profiles of End Use and Used For groups have changed, partially demonstrating what has affected the overall consumption profile. The profiles of End Use, with and without "process" consumption can be seen in Figure 5.23 and Figure 5.24, respectively.

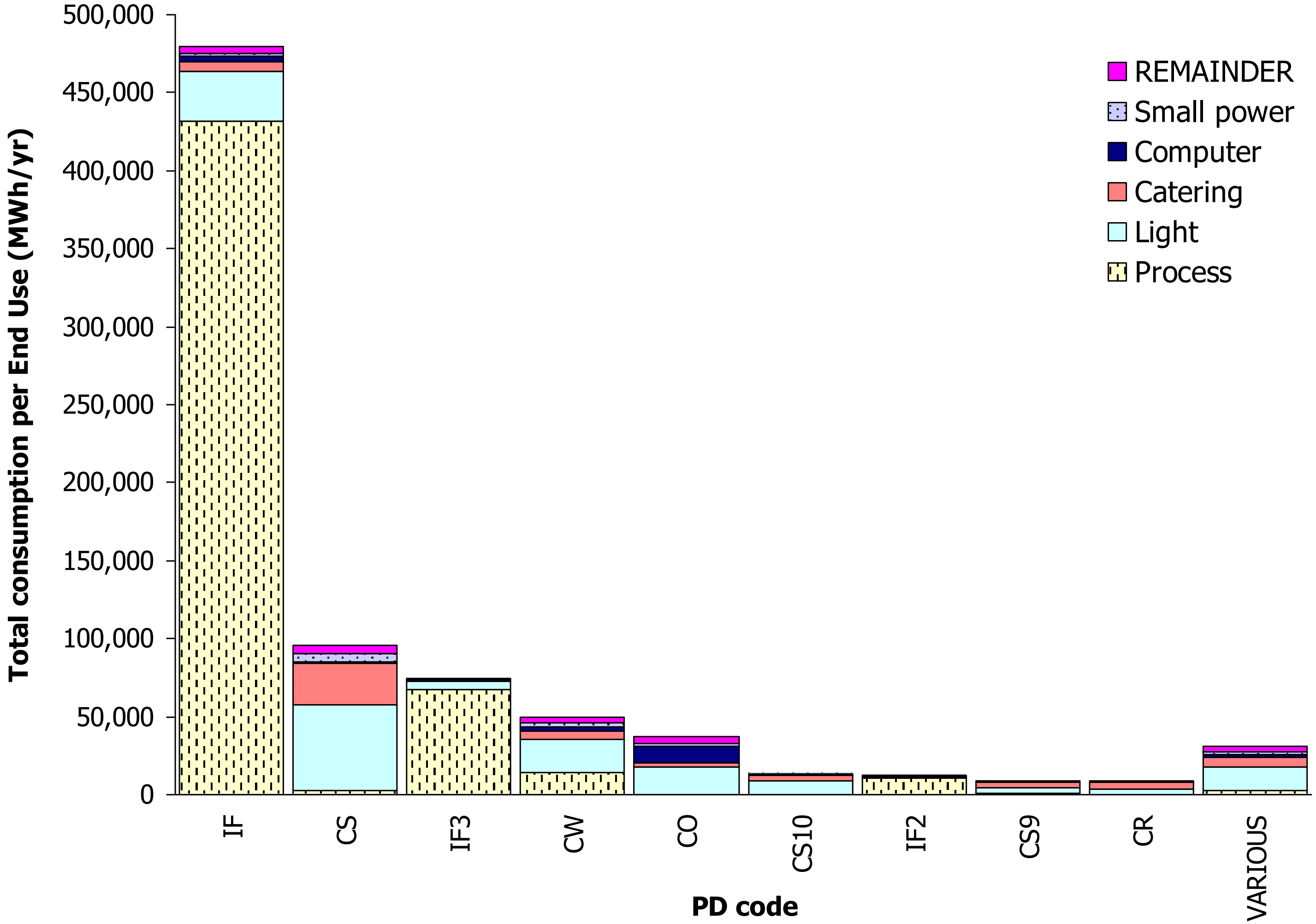

Figure 5.23: Leicester City appliance electricity consumption, per PD code and End Use, using generic Room Use Energy Intensities.

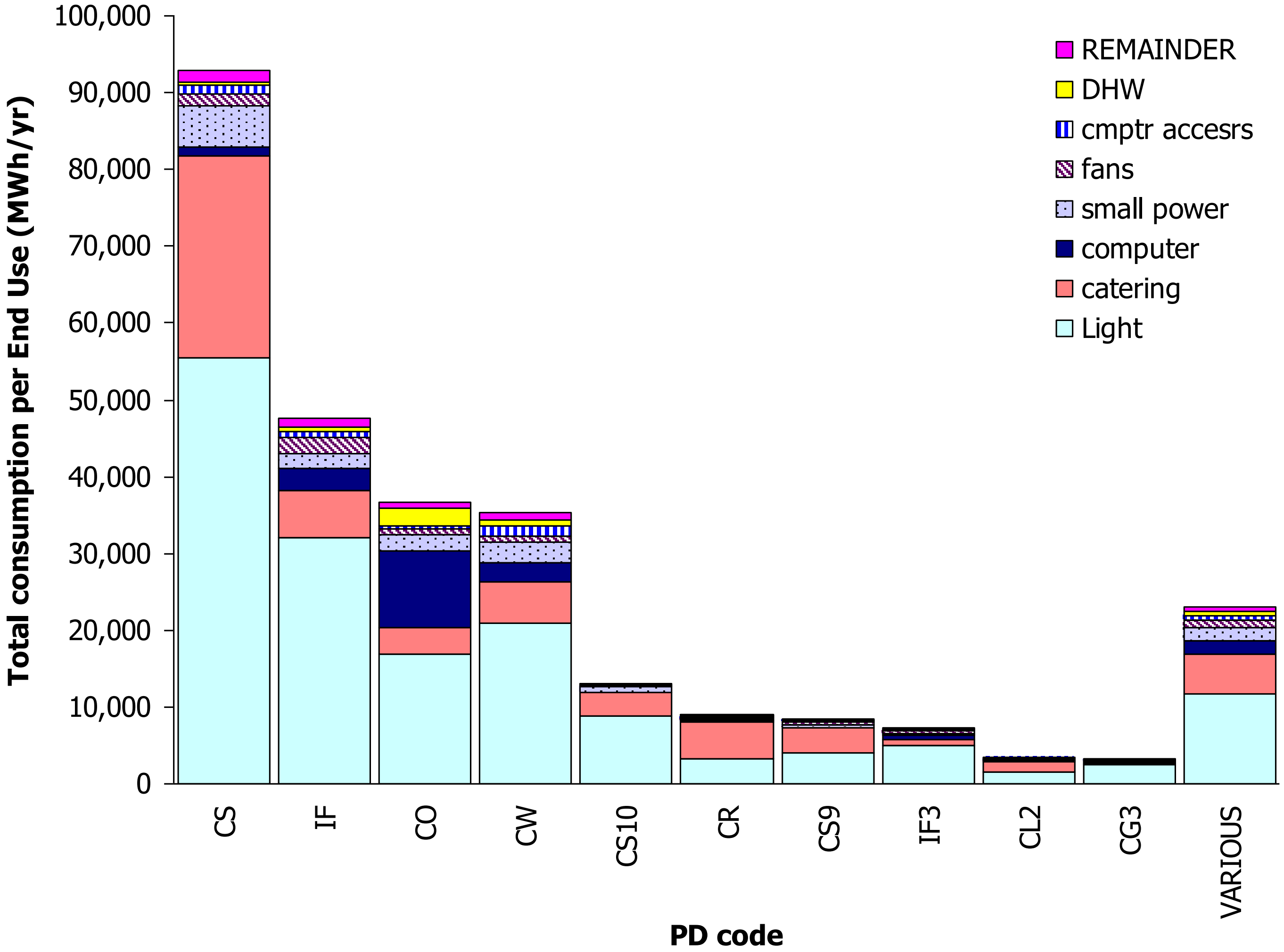

Figure 5.24: Total Leicester City appliance electricity consumption, per PD code and End Use, excluding "process" consumption, using generic Room Use Energy Intensities.

The End Use profile, including "process" consumption (Figure 5.23) is much the same as that shown in Figure 5.15, except for the increase in consumption in Workshop premises (IF3), as explained for the overall profile, above. Comparing Figure 5.24 to Figure 5.17 indicates that the profile of non-process consumption has altered. The consumption, per Primary Description class, has been reduced across most classes, with the notable exception of Factories (IF), in which the non-process consumption has increased – mostly in the "catering" and "DHW" End Uses. This is likely to be due to the low Energy Intensities of these End Uses, in Factories, being inflated by the Energy Intensities of other Primary Description classes. The opposite effect can be seen in Restaurants (CR), where "catering" consumption has been much reduced.

Viewing the consumption by Used For groups, shown in Figure 5.25, again shows the increased "process" consumption of Workshop premises (IF3). The total consumption by Office premises has been reduced, whilst the "process" consumption of Warehouses (CW) has increased their overall consumption.

In Figure 5.26, showing consumption excluding "process", the most striking difference is in the consumption attributed to "transport". The level of consumption identified as "transport", in Factories, is extremely high. This is thought to be caused by the "process" Room Use, in Warehouses in the SHU data, having high Energy Intensities resulting from appliances associated with fork lift trucks (primarily battery charging equipment). These high consumption appliances inflate the Energy Intensity of the generic Room Use "proc" (process), which is the predominant Room Use applied to The SMV Factory Line Description "Production Areas". As this Line Description accounts for 22% of Leicester's floorspace, the effect is commensurately large and increased by other Line Descriptions (and New Line Descriptions) that also use the SHU PD code and Room Use combination, "IF" and "proc".

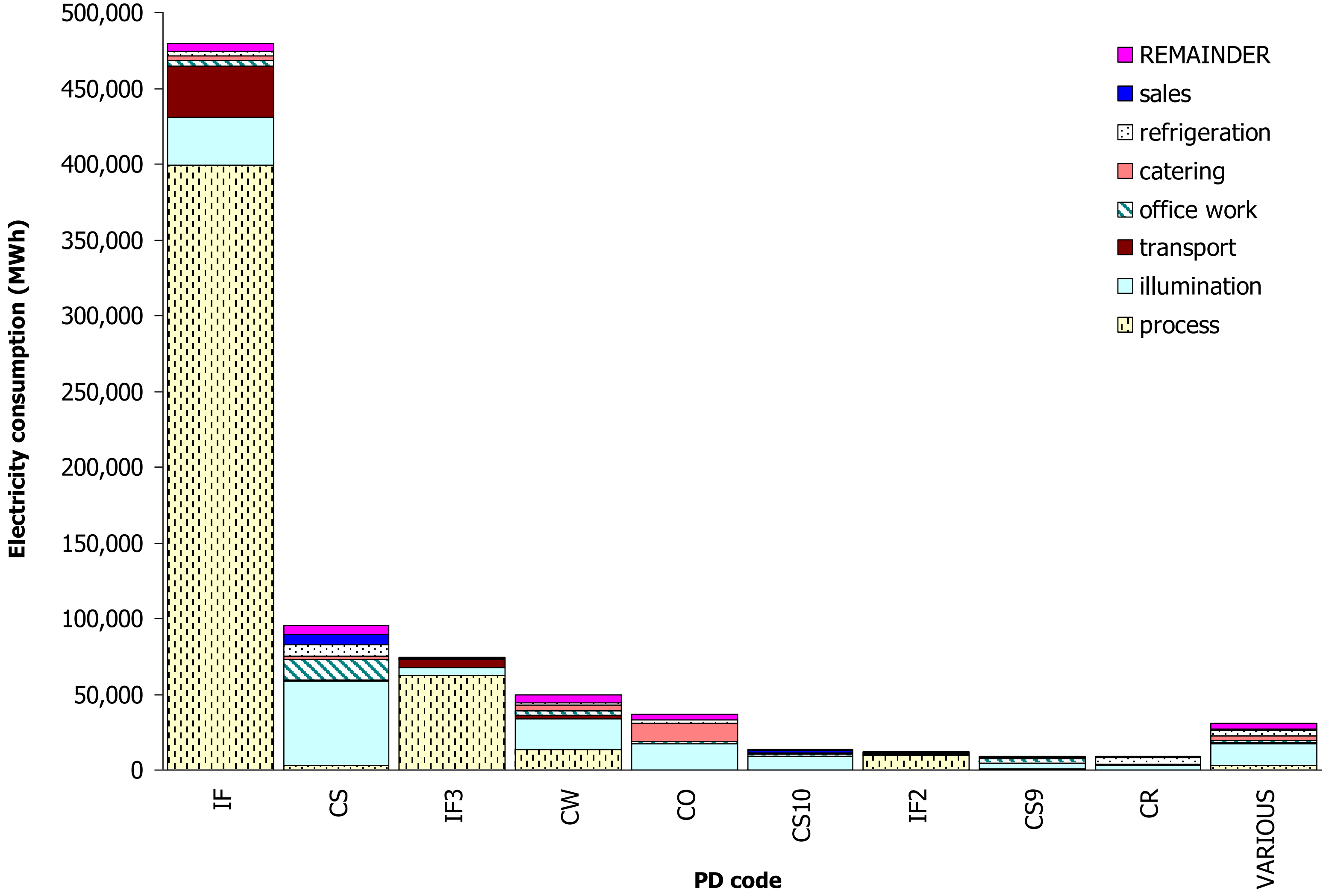

Figure 5.25: Total Leicester appliance consumption, by PD code, per Used For group, using generic Room Use Energy Intensities.

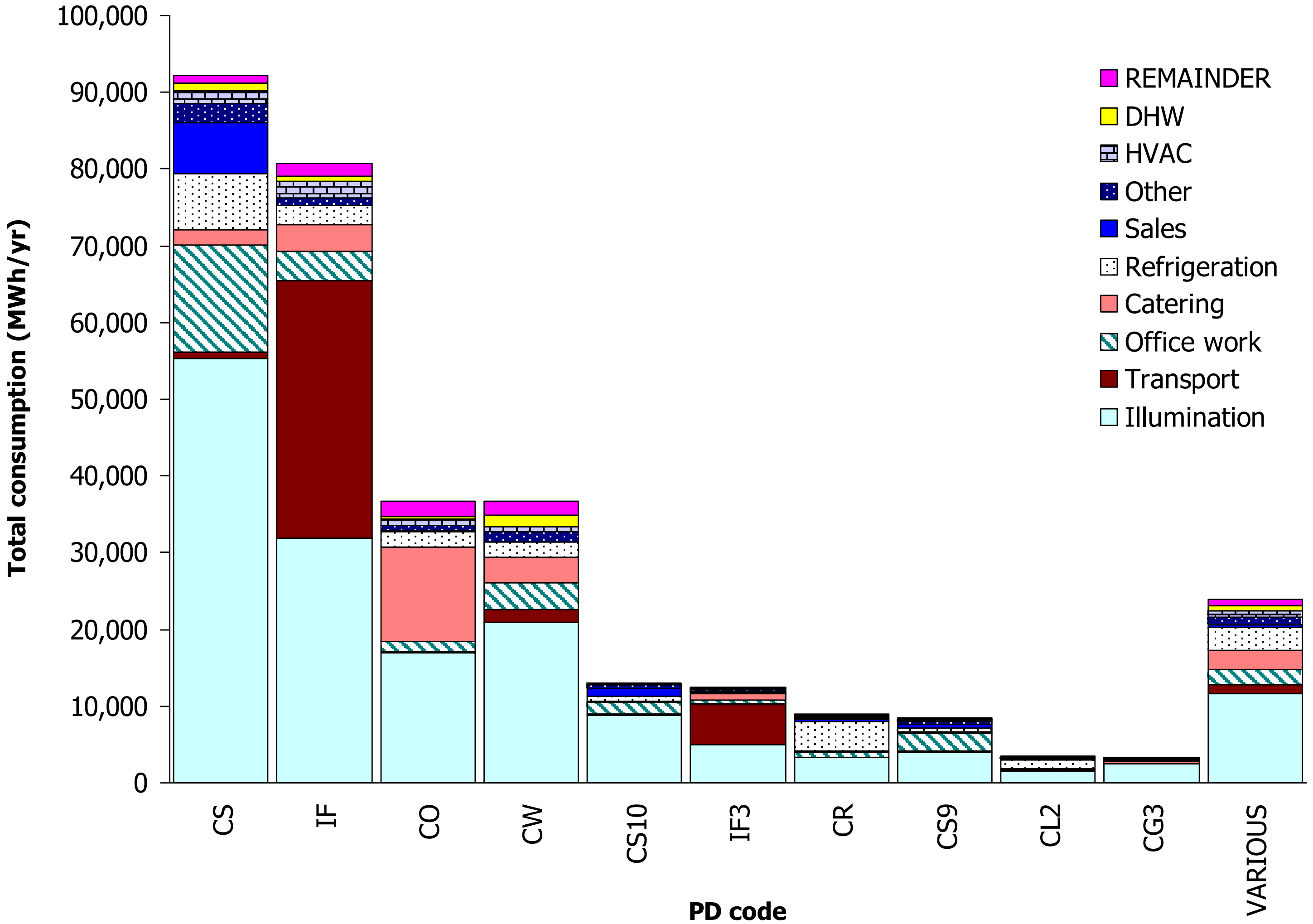

Figure 5.26: Total Leicester appliance consumption, by PD code, per Used For group, excluding "process" consumption, using generic Room Use Energy Intensities.

Further subdivision of the “transport” Used For group, into the categories of Transport of Goods (code “TGoods”) and Transport of People (code “TPpl”), would allow the TGoods to be reclassified as “process”.

The use of generic Energy Intensities, derived from all instances of each SHU Room Use, has not delivered realistic patterns of consumption, when analysed according to Used For group, though further development and refinement of the method may produce reasonable results. This method of calculating appliance electricity consumption, using generic Energy Intensities per Room Use, would benefit from improved samples of premises, both in numbers and number of types. Also, as observed in Section 3.12, improved sample sizes might deliver a more concentrated spread of Energy Intensity values, per Room Use, even though the overall diversity may increase due to outliers. However, the combinations of End Use and the activities for which appliances are used (Used For) could also increase, making analysis by these categories slightly more problematic, using generic profiles.

5.7 Evaluation of Intervention Scenarios

As the data behind this research’s method (i.e. the SHU Surveys data) have an audit trail, it is possible to create new database tables with modifications to individual premises, rooms and even pieces of equipment. Through this, there is the potential to evaluate the effect of an energy consumption intervention, with some degree of precision. As a demonstration of this potential, the scenario of a single intervention has been tested.

The improved efficiency of lighting may be seen as a fairly straightforward means of decreasing electricity consumption and consequently helping to address the problem of resultant carbon dioxide emissions. An intervention scenario was chosen where all tungsten halogen lamps, used for “general illumination” (according to the SHU Used For classification) in the sales spaces of Shop premises in Leicester, would be replaced with an equivalent Compact Fluorescent Lamp (CFL). To model this scenario, all tungsten halogen lamps, in the sales spaces of the cleaned SHU Shops sample, were replaced by equivalent CFLs. The consumption of these appliances was then recalculated and all relevant downstream data and analyses were updated.

A number of assumptions and caveats are applicable to this process:

- It was assumed that all general illumination tungsten halogen lamps were 240V and thus able to be replaced with CFLs
- Only the item code and Wattage of the lamps were changed, in the SHU data, then the consumption was recalculated. The altered wattages were (CFL equivalent to halogen): 11W=50W, 9W=40W, 9W=35W, 7W=20W (energybulbs.co.uk, 2011)
- The SHU:VOA map was left unchanged, so the intervention extends to all Line Entries that make use of the following SHU PD code, Room Use, Used For group combinations:
    - CS sal 10 (illumination); CS GENERIC 10; GENERIC sal 10

The effect of the intervention scenario is very minor: a 0.4% reduction in the total consumption by appliances in Leicester. This is a 3.2 GWh (or 1%) reduction in the total consumption, excluding process. The latter effect is shown in Figure 5.27, below.

The method for modelling this scenario does affect Line Entries beyond the sales spaces in Shops. However, in view of the overall effect being so small, the non-shop sales spaces have an even smaller effect on the result. The model indicates that the consumption by sales spaces of Shops within the CS PD code classification only, in Leicester City, would be reduced by 2.4 GWh, or 4.2% of the original consumption attributed to illumination in Shops. Large Shops (CS9) and Retail Warehouses (CS10) etc, increase this to 3.1 GWh and 5.1% (included within the 3.2 GWh total, above).

Figure 5.27 also indicates the overall effect of the scenario, across the major users of non-process electricity. When compared to Figure 5.21, there is little noticeable change. The 4.2% reduction in Shop "illumination" consumption is not large, but where the retail areas of Shops are cooled, the reduction in internal gains would also result in a reduction in energy consumed by space cooling equipment. In sales spaces containing refrigerated sales appliances, without remote chillers, such appliances would also use less electricity, due to the room temperature being lowered by reduced internal gains. So, although the change of lamps may only result in a direct reduction of 1%, the knock-on effects could slightly improve the effectiveness of the intervention.

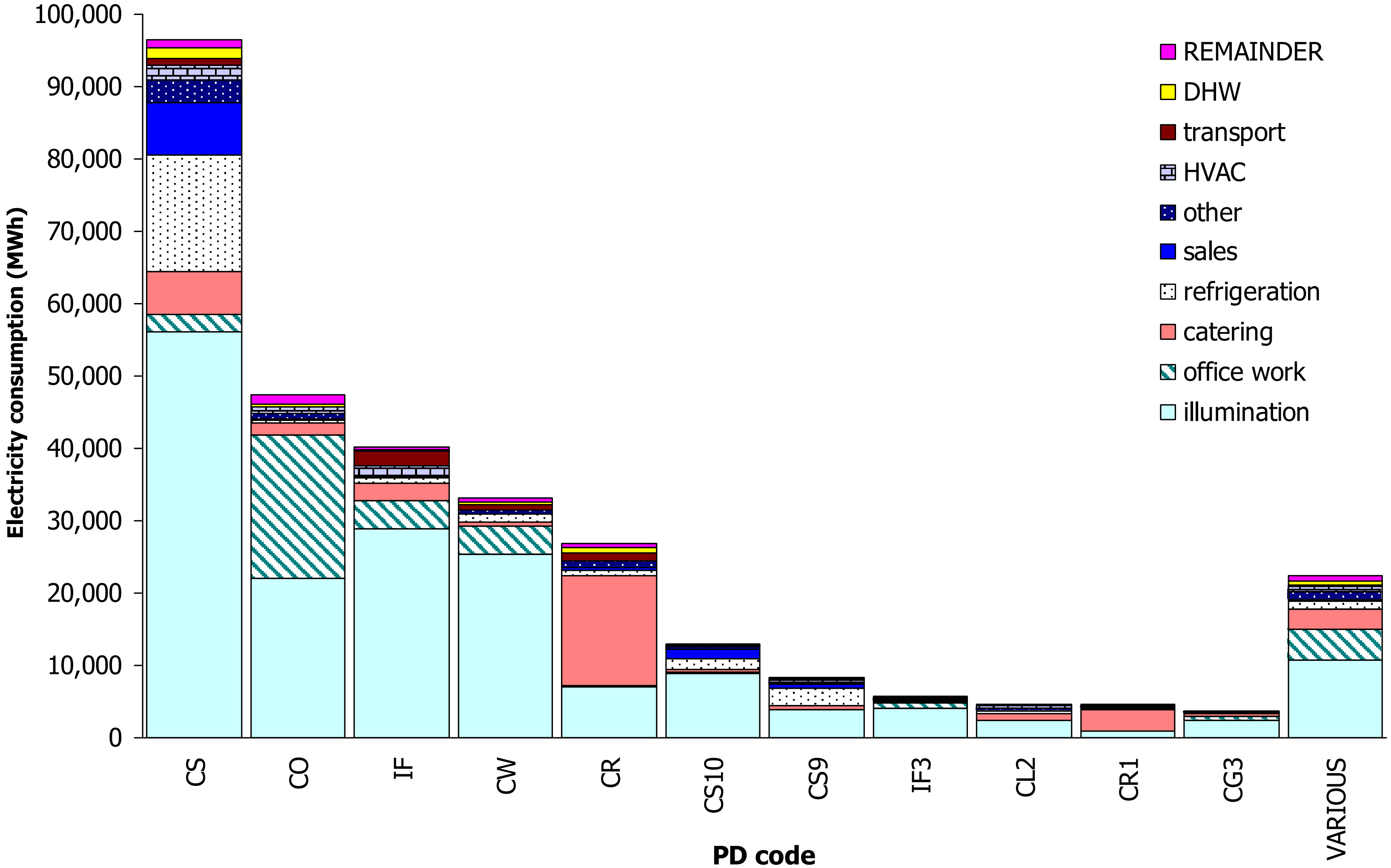

Figure 5.27: Profile of electricity consumption, per Primary Description class, per Used For group, demonstrating the effect of a lighting intervention scenario (excludes process).

This scenario of reducing the electricity consumption of lighting in shops can be given a clearer perspective. The 4.2% reduction in consumption for illumination in shops ought to result in a reduction of 1,277 tonnes of carbon dioxide (CO_2) emissions, per year. This is calculated using an emissions factor of 0.5246 kg CO_2 per kWh of grid electricity (Carbon Trust, 2011). A one percent reduction in the consumption of process electricity, in the Factory premises of Leicester City, would result in emissions being cut by 2,481 tonnes.

In terms of proof of concept, this energy consumption reduction scenario demonstrates how the method might be used for detailed stock energy modelling. However, for the method to be more user friendly, further work would be required to hone the SHU:VOA Map to create greater accuracy and flexibility in how the SHU Energy Intensities are mapped onto VOA Line Descriptions. Further development of the model along these lines would be greatly aided by an improved and expanded database of premises and room use combinations gathered through further, statistically-targeted, energy surveys of premises.

5.8 Summary of Chapter 5

This chapter has shown how the input data, from the VOA, were affected by the relevant cleaning and filtering aspects of the methodology. This should be seen as a significant part of the methodology, as without it the number of premises and floorspace, in particular, would be greatly over-estimated. The latter point is especially important as the overall method infers appliance electricity consumption and consequent internal gains, per unit floor area.

The use of floor area has been discussed and compared to the profiles of space use drawn from the SHU data. Some similarities were found, but also some substantial differences. The overall appliance electricity consumption and internal gains value, calculated by the method, have also been discussed, together with where and how the energy is being consumed.

The potential for the disaggregation of premises into their component Line Entries, according to their Line Description, to describe the heterogeneity of activities within the stock, has been discussed. This method has the potential to place internal gains into the subdivisions of space within premises, without (to a large extent) resorting to assumptions about the use of space. This means that the calculation of internal gains is not performed on a homogenous area of premises activity but on more precise descriptions and measured areas of activity.

The calculated consumption figure has also been compared to the DECC measured electricity consumption for the local authority area of the test urban area, the City of Leicester. The calculated electric appliance consumption (and thus the consequent internal gains) is considered to be acceptable, if a little high. But the overall method appears to be fundamentally sound. There are, however, a small number of qualifications surrounding the result, mostly stemming from the limitations of the data, upon which the method operates.

The analyses of consumption per End Use and Used For groups provide some degree of disaggregation of the overall calculated consumption, giving indications of where internal gains occur and the types of equipment that cause them. This aspect of the work has been explored, further, through the creation and brief analysis of a hypothetical energy consumption intervention scenario, showing a potential use of the model.

The model has also been re-run but using generic Room Use Energy Intensity values, rather than Primary Description and Room Use specific Energy Intensities. This aspect of the research was less successful, but requires further work – particularly increased numbers of samples – to properly evaluate its worth.

Chapter 6: Conclusions

This chapter reviews the achievements (Section 6.1) of this research in the light of the four main objectives and the overall aim, set out in Chapter 1. Each objective is reviewed, in turn, and the achievement of the overall aim is then assessed. Section 6.2 discusses the limitations of the research, whilst Section 6.3 describes further work that would help address these limitations and provide further practical benefits to stock modelling.

In Chapter 2, the concept of Layers of Change, in buildings, was discussed alongside the effects of layers of access to data. How these layers align with the processes involved in detailed energy surveys of buildings and premises and the recording of the information gathered was also described. The Recommendations Section 6.4 lays the groundwork for how the combining of these concepts, may be used to form a new energy survey method and structure. The enhanced method would provide a significant and practical improvement to the alignment of detailed energy survey data with Valuation Office Agency datasets and information used for design guidance and regulatory compliance.

6.1 Achievements

6.1.1 Space Usage Profiles

The first objective of this research was to "Develop a method for inferring space usage from accessible building and premises data."

Previous UK non-domestic building stock energy consumption models have not used information at a resolution finer than whole premises and the subdivision of premises into activity areas was not addressed. This thesis has taken detailed energy surveys (the SHU data) and analysed them to produce profiles of space use within a range of non-domestic premises types, classified according to the Valuation Office Agency's Primary Description categories. Analysis has provided space use profiles for sixteen premises types, together with profiles of appliance electricity consumption for each space use.

The non-domestic stock is extremely diverse in its activities. Within the SHU datasets, this is represented by the many combinations of premises Primary Description and

Room Use found in the sample premises. It is clear from the analyses of these samples that premises of a similar type do not all contain the same Room Uses. This represents a form of heterogeneity that is not included when modelling the energy consumption of the stock, using a method based on whole premises.

Further evidence of diversity has been provided by the spread of values for the proportions of premises' areas used for some Room Uses, within each Primary Description class. Where they occur in premises, there is a spread of values for the proportion of premises' total area used for a given activity. However, when using a whole premises model to estimate stock energy consumption, this diversity is only held within mean or typical values of the overall use of space. By subdividing premises into their various activity areas, the modelling process moves away from typical and mean values and closer to measured values of space use. As a result, more precise modelling becomes feasible.

Further analyses have indicated that some non-core support activities tend to occupy areas that are largely proportional to the overall area of the premises. So, much of the diversity in space use in premises types appears to occur within what may be seen as the core activity areas of premises, such as office work in office premises. Also, as sample sizes of premises increase, so it seems that the variability in the proportion of space used for core activities also increases. It follows that identifying the actual area used for an activity within premises, rather than inferring it from the analysis of sample premises, will lead to greater precision in building stock models.

6.1.2 Profiles of Appliance Electricity Consumption

Objective two was, "Infer values for the electricity consumption of appliances, and hence internal gains, for space uses within premises." After the exclusion of equipment with the End Uses "heating" and "cooling", the Rooms used to generate the space use profiles described above, were filtered and analysed further to produce Energy Intensity (kWh/m^2/year) and End Use profiles for those Rooms. This gives a mean Energy Intensity for each Room Use found in each of the sixteen Primary Description (PD) classes. Generic values for Room Uses, ignoring the PD classes, were also produced.

In addition to the bare Energy Intensities, profiles for fourteen End Uses of appliances were also generated. A new set of grouped classifications, describing what the appliances were used for was generated alongside the End Uses, to provide further detail. Generic profiles of both of these were also produced, i.e. profiles per End Use and Used For group, per Room Use, taken across all PD classes.

The analysis of Energy Intensities of Room Use generic profiles indicated that Energy Intensities were often broadly similar for a given Room Use, irrespective of Primary Description class. There were, however, sufficient differences to suggest that the use of Room Use and PD code combinations is a more reliable indicator of energy consumption characteristics. That said, it is still more desirable to describe space use according to Room Use than PD code. For example, an area used for office work in factory premises is best described as an "office" than to merely describe it as "part of a factory". So, the generic values for each Room Use are of benefit when estimating the appliance electricity consumption and consequent internal gains in spaces for which there is no Room Use and Primary Description combination, in the SHU analyses, available for use in an energy consumption model.

The method overcomes the constraint, not currently addressed when modelling at the level of whole premises, that not all Room Uses appear in all premises of a given Primary Description. In this research, the Energy Intensity of each Room Use is the sum of all appliance electricity consumption, across all similar Rooms in the relevant Primary Description class sample, divided by the summed floor areas of the Rooms in which the consumption occurs. Consequently, appliance consumption characteristics may be applied to measured subdivisions of space use identified within premises included within stock energy consumption models. The increased precision in the identification of space use, within premises, in turn allows the types of energy consuming equipment within the entire premises to be inferred with improved accuracy, because certain types and numbers of appliances can be associated with each activity space.

6.1.3 Application of Space Use and Energy Intensity Profiles at the Urban Scale

The third objective was, "Apply the method to a dataset at the urban scale and use a suitable model to deduce the energy consumption."

This research has taken the profiles of space use, Energy Intensities and appliance use, summarised in sections 6.1.1 and 6.1.2 above, and applied them to a city scale dataset of premises. The result is a calculated estimate of electricity consumption by electrical appliances, and hence internal gains, in subdivisions of premises in the city. The source of the urban scale data was property taxation data from the Valuation Office Agency (VOA), providing information on premises – primarily overall premises activity, subdivisions of premises' overall areas and the activity within those subdivisions. The VOA data were for the year 2008 and were provided in the form of the Rating List and Summary Valuation (SMV) databases for the Billing Authority area of the City of Leicester.

The VOA databases required filtering and during this process discrepancies were found between Primary Description codes and premises Descriptions (held in the VOA Rating List), with SMV premises Line Descriptions indicating uses of the subdivisions of premises that did not always tally well with the overall premises activity. The research also suggests that the Line Description may be a more up-to-date and thus more reliable indicator of activity than the Primary Description. In view of this, the Line Description has been used as the initial identifier of space use, followed by the premises' Primary Description (PD) code – the Line Description is thus the primary classification of space use, with PD codes as subcategories.

Discrepancies between the recorded "Total Area" of premises, in the VOA SMV, and the sum of Line Entry areas for each premises, were also found. The overall discrepancy was small, but was substantial in a small number of premises. As a VOA premises valuation is based upon the sum of monetary values given to Line Entries, not the Total Area, the sum of Line Entry areas was used to represent the total area of premises during this research. The use of the combinations of Line Entry Area and the Line Description provides increased detail and flexibility when applying energy consumption profiles to premises, as previously indicated by the analyses of the SHU datasets.

Some Line Entries in the test area had no recorded area, so 1,597 Line Entries in the SMV, for non-core support activities with no recorded area, had their floorspace inferred, based on the SHU space use profiles. Line Entries measured to the Valuation

Office Agency Net Internal Area (NIA) convention, were increased to give Gross Internal Area (GIA) to match the GIA measuring convention used in the SHU profiles.

Initially, using the Line Descriptions attached to Valuation Office Agency Accommodation Use Codes (AUC), 84.8% of Line Entries and 81.2% of the summed SMV Line Entry areas could be readily identified and the area captured for the inference of appliance Energy Intensities and use profiles. Further data processing allocated remaining Line Entries to one of the AUCs, or one of 59 other descriptors. At the end of the process a total of 94.4% of Line Entries and 96% of the summed Line Entry areas were identified and captured. Of the total SMV area, 91.5% was categorised as internal and suitable for the estimation of internal gains.

It is conventional to consider space use within premises to be a subdivision of those premises, so this is how the combination of Primary Description code and Line Description has been described, in this work. However, methodologically, this research has departed from the convention of considering space use within premises as a subdivision of the premises' activity. Instead, the area subdivision's Line Description is given precedence over the premises' overall Primary Description, so the inference of appliance electricity consumption and internal gains is very much a bottom-up methodology. Effectively, the overall classification of space use is at the Line Entry level, with subcategories of Primary Description codes, when applying energy consumption profiles, from SHU analyses, to the VOA datasets. This method allows the choice of a Room Use from the SHU analyses that is judged to match the characteristics of the Line Description and Primary Description combination (in the VOA datasets) most closely. By this method, it is easier to overcome the limited number of data for Primary Description codes in the SHU analyses.

The strength of this approach is enhanced by the discrepancies between premises' summed Line Entry areas and premises' Total areas in the SMV. The use of the Line Description as the initial identifier of space use, followed by the premises' Primary Description (PD) code as a subcategory, together with the Line Entry Area, is a logical progression.

The SHU:VOA Map was devised to allow the SHU-derived energy consumption profiles to be applied to the VOA premises taxation data. This Map aligns combinations of between one and seven Room Uses, in one Primary Description (PD) class from the

SHU analyses, onto VOA Line Description and Primary Description combinations. To fit with the conventions of pre-existing research, these combinations are shown as Primary Description code and Room Use.

The anticipated constraints, resulting from small sample sizes for some of the sixteen premises types in the filtered SHU data, were largely overcome because the subdivision of premises into Room Uses effectively increased the sample size of each use of space. So, although there were some premises types with very small samples, the subdivision of each premises into Rooms and the repetition of Room Uses in premises increased the sample sizes of Room Uses per PD class and generic non-PD-specific Room Uses.

However, the range of premises types (available from the filtered SHU data) did affect the ability to apply, directly, the outputs of the SHU analyses to the VOA Line Entries. To overcome this constraint – where no exact match of PD code is available from the cleaned SHU data, for application to the SMV Line Entry – the SHU:VOA mapping process takes one of two paths. Either a generic profile for a Room Use (ignoring PD codes) is chosen, or a suitable Room Use(s) from another premises type from the SHU analyses, is applied to the VOA PD code and Line Description combination (in the SMV). This feature makes use of the indications from the SHU analyses that the energy consumption characteristics of a given Room Use are more representative than the overall use of the premises type(s) in which it appears.

After the application of the SHU:VOA Map to the SMV of the test urban area (City of Leicester), the overall result is that the method is able to estimate appliance electricity consumption and consequent internal gains, per Line Entry, for 91.5% of the summed area of Line Entries in the SMV. The internal gains also affect the heating or cooling loads moderated by the operation of heating, ventilation and air conditioning (HVAC) equipment in premises.

6.1.4 Deducing the End Uses of Consumption

To add value to the bare Energy Intensity profiles, the SHU:VOA Map was used to apply End Use profiles (from the analyses of SHU samples) to Line Entries in the test area VOA SMV. This enables inferences to be made about the types of appliances that consume electricity in different parts of premises and how they affect internal gains.

A new grouping of Used For codes was also devised, to further explain the activities and their associated appliances in SHU Room Uses and, hence, the test urban area's Line Entries.

As the method can infer electricity consumption for a number of End Use classes and Used For groups, flexibility of application has been incorporated into the model and any larger model to which it may contribute. For example, "process" appliance consumption can be excluded from the inference of internal gains. This means that premises with significant appliance process energy use, such as factories, may have their internal gains calculated to indicate how their energy consumption is affected by non-process consumption, both in discrete measured areas used for process activities and in other discrete measured areas of space uses such as office work, canteens and storage. Previous whole-premises approaches to stock energy modelling have not done this, as it has only been possible to infer these areas, their consumption and their internal gains, from an overall homogenous premises class profile.

Estimations of what the modelled electricity consumption is used for were mostly satisfactory and reasonable. However, the use profiles of a few of the Room Use types are felt to be unreliable – primarily Restaurant and Café kitchens – due to what are considered to be unrepresentative samples in the cleaned SHU datasets. These Room Uses do not represent large numbers of Line Entries, or large parts of the total area of the SMV and thus do not have a large influence on the overall results. A larger sample of this Room Use and premises type would improve the reliability of the data and analyses.

6.1.4.1 Modelling, Using Generic Values

In addition to the principal method of estimating consumption, using Room Use and PD code combinations described above, the method was repeated using information derived from generic Room Uses, regardless of Primary Description class. Although the overall appliance consumption figure, for the test stock, was almost identical, the profiles of where and how energy was used were substantially different, for some Primary Description classes. Further work and increased numbers of data may improve this version of the method, but the PD code-specific primary methodology appears to be a better approach, at present.

6.1.4.2 Demonstration of an Intervention Scenario

Finally, the model was used to test an energy intervention scenario involving the replacement of halogen lighting with equivalent compact fluorescent lamps in the sales spaces of shops. The scenario demonstrates how the model can be targeted for evaluating interventions and how it might be used in practice.

6.1.5 Comparison of Results to Measured Consumption

The fourth objective was to, "Compare the results with measured data."

For the test urban area, the City of Leicester Billing Authority area, the appliance electricity consumption was calculated to be 788.6 GWh. This value represents 75.2% of the DECC figure of 1047.9 GWh recorded for the non-domestic sector of the City of Leicester in the year 2008. This research's calculated figure does not include:

- 5.6% of Line Entries in the test area SMV
- premises that appear in the Leicester City Rating List, but not in the SMV
- premises that do not appear in the Rating List
- consumption attributed to heating or cooling appliances (as defined within the SHU datasets)

In view of these exclusions, the calculated figure is acceptable. The methodology assumes that all premises are occupied and in use, which is unlikely to be the case in reality. This gap between occupied and unoccupied premises may also partially explain the difference between calculated and recorded consumption.

For the year 2008, the combined domestic and non-domestic electricity consumption of the City of Leicester was 1501.9 GWh, so this model has been able to infer that slightly more than half of this consumption is by appliances in identified space uses within non-domestic buildings.

6.1.6 Evaluation of Achievement of the Overall Aim

The overall aim of the research was, "To improve the prediction of energy consumption in the non-domestic building stock by developing a method to infer the electricity consumption of appliances, and resultant incidental heat gains, for the internal space uses of premises, as identified in UK property taxation data."

The results suggest that the methodology of this research has met the overall aim, but the methodology has only been tested on the property taxation dataset of one urban area (the City of Leicester), so this should be seen as a proof of concept, only. How these inferred internal gains are applied to and affect the operation of stock energy consumption models that might use such data, has not been assessed.

The test VOA datasets suggest that Line Descriptions are a more reliable indicator of the activities occurring in premises than the Primary Description code. By basing the estimation of consumption on these Line Descriptions, with Primary Descriptions as subcategories, the modelling of consumption should be more accurate. Also, if over time, how space is used within premises changes at the Line Entry level, the subsequent change in consumption can also be modelled. This is especially the case where the Primary Description has remained unchanged. This is an advance upon previous premises-based models, which use space use and consumption profiles based upon homogenised premises samples.

The methodology may also be seen as a contributing component, for a larger overarching stock description classification. The ability to identify subdivisions of premises and infer their internal gains characteristics, goes much of the way to meeting the requirements of Bruhns et al , as they are described in Section 2.2.3 Requirements of a Non-domestic Activity Classification System, on page 29.

Also, as the methodology includes the ability to infer the types and End Uses of appliances, it is possible to estimate how changes to appliances and the spaces associated with their operation (or vice versa), will affect electricity consumption. Additionally, if used as an input to a suitable model, it may be seen how the internal gains affect the energy consumption of HVAC systems of Line Entries, premises, buildings and the stock.

6.2 Limitations

This section examines the overall methodology described across Chapter 3 and Chapter 4, to identify limitations. From this, a number of potential refinements of the methodology and the underlying data are proposed and discussed in Section 6.3 Further Work. Key assumptions are also discussed.

6.2.1 Inferring Characteristics of Line Descriptions

Currently, the methodology is not able to infer Energy Intensities or End Use profiles for some of the Line Entries in the SMV, namely:

1. Multiple descriptions of Line Entries, for example "Office/Kitchen", cannot have their EI inferred, as it is not known what proportion of the space is office and what proportion is kitchen.
2. Line Descriptions of no value, in terms of describing the use of the space, for example "Zoned from Market Place".
3. Line Descriptions that are unique and cannot be identified in a systematic manner, using a reasonable amount of effort.

6.2.2 Premises not Recorded in the SMV

There are also premises in the Rating List that do not appear in the SMV, plus buildings that do not appear in the Rating List. The number of the former can be known, but there are no accessible records for the latter. As the method relies on the ability to infer appliance energy characteristics from Line Descriptions, these premises are beyond the immediate capability of the methodology.

6.2.3 Methodological Assumptions

Due to the scarcity of reliable data on some aspects of the characteristics of the non-domestic stock, it is necessary to rely on a number of reasoned assumptions.

6.2.3.1 Energy Consumption Characteristics

The first set of assumptions, centred upon the SHU energy survey data and their analyses, are as follows:

1) The SHU data (and updates performed within this work) are representative of the stock being modelled. The constituent parts of this assumption are:
    i) The SHU premises' occupancy hours are representative of the premises' Line Entries, in the test area's SMV.
    ii) The annual consumption of appliances, in Primary Description code and Room Use combinations is correct. This is partly dependent upon i) above, but also upon the wattage, load factor and utilisation factor of each appliance – particularly the default values of these.

iii) There have been no significant changes in the types and numbers of appliances, or their use, in the PD code and Room Use combinations used in the SHU:VOA Map – other than those changes described and applied in the methodology – since the SHU energy surveys were carried out.

iv) The total appliance electricity consumption, End Uses and proportional use of space and so forth, derived from the appropriate SHU Primary Description class sample, are assumed to be representative of premises in the SMV, which use the single Line Description "All Main Areas" (or similar).

The overall justification for 1) is that for some of the Primary Description classes there may be small sample sizes of premises, but in terms of the number of rooms of a given type, per Primary Description class, the sample size is more robust and ought to make subsequent analysis outputs more reliable. Each of the constituent assumptions is based upon the SHU sample data being the only such large-scale accessible dataset that is thought to be representative.

The justification for assumption iv) is that the Line Description "All Main Areas" (or similar) is mostly attached to Shop premises, which have the largest sample size in the SHU datasets and are subsequently seen as being robust.

6.2.3.2 VOA Data

The assumptions relevant to the VOA datasets are:

1. The VOA data are largely reliable. This is particularly important for the three key pieces of input data: PD code; Line Description; Line Area.
2. This research's interpretation of Line Descriptions, in terms of their description of the use of space, is accurate.
3. All premises are occupied. This is likely to overestimate the total consumption for the area being modelled.

Assumption 1 is generally held to be the case within the field of UK non-domestic stock energy modelling and this research conforms to this assumption, although this research judges that Line Descriptions are more representative of activity than Primary Descriptions. Assumption 2 is fair, considering the usually straightforward terminology used in describing activities and spaces. As there is no accessible information on the occupancy of premises, in the test urban area, the assumption (3) that they are all occupied is reasonable.

In terms of the SHU:VOA Map, it is assumed that correct judgements have been made when mapping SHU Room Use(s) and Primary Description code combinations onto Line Description and Primary Description combinations.

6.3 Further Work

6.3.1 Improving Line Description Identification

Refinements to the methodology ought to be able to overcome the limitations imposed by multiple descriptions in the Line Description field. A potential solution is to analyse the SMV for proportions of space use in premises – in the same manner that the SHU data were analysed – to determine the patterns of space usage in premises types. From these, it should be possible to infer the relative areas of each part of many multiple descriptions, in each Primary Description class. The Line Entry's area would then be split accordingly, into the relevant descriptions. The identification of Line Descriptions would still be subject to diminishing returns on the effort expended and descriptions of no practical use would remain, though these have been found to be small in terms of percentages of both numbers and total area.

6.3.2 Electricity Consumption of Premises not Recorded in the SMV

The method is able to calculate the appliance electricity consumption of much of the non-domestic stock of the test urban area but not all of it. During the progress of the research, this limitation has been accepted, but the inability to identify consumption by premises that are not recorded in the SMV has not been addressed. It may be possible to partially fill this gap.

It is feasible to gather information about the annual energy consumption of some of the buildings that are not included in the VOA SMV and/or the Rating List. Some of the data contained within Display Energy Certificates (DECs) are accessible from a central source, including annual electricity consumption for the year of issue of the DEC (Centre for Sustainable Energy, 2011). Currently, DECs are required for public buildings over 1000m^2 with public access, so this includes some of the buildings that do not appear in the SMV, such as hospitals, universities, schools and leisure centres.

The consumption identified in the DECs can be used to fill the shortfall between the estimates calculated by the model and the total consumption of the test urban area, as recorded by DECC. There are, however, some problems with this procedure caused by the difficulty of ascertaining just how much of the consumption, external to the model, is being captured. The Rating List has a record for all premises that are rateable and the post code of the premises is also recorded. Unfortunately, it was found that the post code recorded on a DEC does not always match that recorded in the Rating List, for premises that were deduced to be the same premises. So, matching premises by post code, from DEC to Rating List, does not always work and the post code is the only code accessible to this research that can be used to align DEC records to Rating List records.

In this work, it was mostly possible to match the premises by eye, but this is very time consuming and not practical for larger datasets. Having experimented with this method, it was found that there were a small number of overlaps between the DEC records and the SMV; so there are premises in the SMV that also have DECs, making it unreliable to assume that all DEC premises do not appear in the SMV. Further complications arise from there being multiple DECs for the same premises, sometimes dated only a matter of days apart.

In view of the complexities of filtering and aligning the DEC records to the Rating List and overlaps with the SMV, this research has not pursued this method any further and suggests that it warrants further research.

6.3.3 Reducing the need for Assumptions

The limitations, placed upon the methodology, by the assumptions attached to the SHU data could be addressed through access to more data of a suitable nature. Improved sample sizes would make inferences more sound and generally benefit the field of research. The collection of data is beyond the scope of the methodology of this research, but Section 6.4.1 Improvements to Energy Surveys and Datasets, contains details of progressive further work that would help overcome the limitations imposed by assumptions.

6.3.4 Improving Functionality and Adding Value

The tools used for the methodology, though adequate for this research, are not ideal for the processing of larger datasets. A redesign of the methodology, based upon databases constructed from the input data (SHU, VOA Rating List and SMV), coupled to calculation programs able to handle very large datasets, would improve work efficiency and reduce the potential for errors. The most problematic aspect of upgrading would most-likely be automation of the construction of the SHU:VOA Map, which involves engineering judgement; this is likely still to require some work, relying on judgement that cannot be automated.

Further development of the New Line Descriptions could improve the speed of application of the methodology and there may also be some improvements that could be applied to the method of using search strings to identify Line Descriptions. However, both of these are likely to be subject to diminishing returns on the effort expended, as discussed earlier.

Application of the method to VOA data, for other UK urban areas, would enhance the method and progress understanding of Line Entries as a means of honing the estimation of the energy consumption of non-domestic building stocks. This would be of value, even before carrying out the developments indicated above. Improvements are likely to be most noticeable where the intensity of use of space and appliance density are different to those indicated by the SHU data; for example, in the financial trading districts of London, where office Energy Intensities are likely to be much higher, due to high densities of appliances and long hours of operation. Testing the method on such an urban area would highlight the data that need to be collected in energy surveys, to improve the representativeness of the Energy Intensities to be applied to Line Entries.

High rateable values are likely to correlate well with high density occupation of space, due to the commercial desire to make best use of expensive floorspace. It may, therefore, be feasible to adjust the density of appliances – particularly office work equipment – on Line Entries with high rateable values. This would warrant further research.

6.3.5 Sub-City-Scale Consumption

As detailed in Section 5.4, the DECC data of city-scale energy consumption aggregate all consumption passing through half-hourly meters into a single number, for each Local Authority area. As the proportion of half-hourly meters is likely to increase, the amount of consumption aggregated into the single DECC consumption value, may also increase. This would result in it being more problematic to place consumption into spatial subdivisions of cities, namely Middle Layer Super Output Areas (MLSOA).

Although it has not been carried out in this programme of research, it would be possible to estimate the total electricity consumption of appliances in each MLSOA, using this methodology, by cross-referencing each premises post code (from the Rating List) with the post codes attached to each MLSOA. In this way, the model may also be of use to those requiring tools to aid planning decisions, particularly in terms of electrical loads and how these might change with the evolution of how activities are spread, at the sub-urban MLSOA scale, or how technological advances will affect appliances and their use in the non-domestic sector. This may also be of use to those evaluating community scale projects such as combined heat and power installations, where demand loads and how they may change need to be understood.

6.4 Recommendations

These recommendations have been drawn up to enable the methodology of this research to be simplified and enhanced, with the objective of making it more functional, for potential users.

Overall, it is currently the small sample sizes of some of the SHU premises types that are the greatest limitation in the method, so the most significant improvements to the methodology and results are likely to come from an ability to analyse more data, of the type supplied by the SHU energy surveys. An improvement in the number of premises types would make the greatest difference to the applicability of SHU-type data to Line Description and PD code combinations. In view of these, the following recommendations are made.

6.4.1 Improvements to Energy Surveys and Datasets

In Section 2.1.3, Brand's model of Layers of Change, in buildings, was discussed. The problems of access to data, captured by Thuvander's model of concentric layers of access, were also described (Section 2.1.4). The combination of these two models, suggests a structure for a multilayer model of building stock information and method for the collection of information.

6.4.1.1 Survey Layers

It was explained in Chapter 2 that the overall activity performed inside a building is not necessarily dependent upon the physical characteristics of the building and that buildings are a unit of construction, whilst premises are a unit of operation. When considering Brand's Layers of Change model, the building is mostly represented by the Layers "Site", "Structure" and "Skin"; and partly represented by the Layer "Services". The "Space Use" and "Stuff" Layers logically describe premises. The Line Entries of the VOA SMV and the Room Uses of the SHU surveys, describe the "Space Use" Layer. The records of appliances, in the SHU surveys, mostly represent the electrical "Stuff" (but not the Stuff that uses other fuels). The "Services" Layer is akin to a moderating interface between the premises and the building, enabling the premises (Space Use, Stuff and occupants) to operate within the building fabric (Skin and Structure) on the Site.

The detailed development of such a model falls under the heading of "further work", but many of its components are already contained within existing research. However, looking at the information and survey structure as a contributor to a layered geographical information system (GIS), it may be seen that the Stuff layer would underlie all other layers. This is as it should be, for it is the use of equipment, associated with activities, that drives energy consumption in premises, buildings and the stock as a whole. Above this layer should be data on the use of space, recorded according to both the energy survey classifications and the VOA classifications. The inclusion of this layer would most-likely obviate the need for the SHU:VOA Map process, as the relationships would be recorded, understood and applied with greater ease, than in the methodology of this research. This layer of information would negate the need for the assumptions made in the generation of the SHU:VOA Map, as identified in Section 6.2.3.2, above

As appliances can be associated with the use of space in surveyed premises, it is possible to associate appliances and their electricity consumption (and internal gains) with the Line Entries of the SMV – as demonstrated in the SHU:VOA Map. The VOA data, due to their legal status, must fall into the "existing data" layer of access, so this goes some way to overcoming the problems of layers of access to information about premises, because access to some VOA data does not require internal access to the premises to be modelled.

The survey methodology should also be able to align data, more easily, with classifications of space use taken from building design practice. This ought to allow the identification of patterns of how building designers categorise space in relation to survey Room Uses. As the three classifications of space use – VOA, surveys, building design – could be accurately aligned, the effects of changes in the stock may be interpreted in terms of empirical data about energy consumption, changes of space use, and changes in design practice. By linking the contents of regulatory compliance and design values to VOA-compatible space use categories, modelling the effects of interventions and changes to the stock, resulting from Building Regulations, refurbishments, town planning and suchlike, will be more-easily facilitated

6.4.1.2 Changes in Characteristics

The Layers of Change structure for a building stock information and survey model also indicates the speed of change of each Layer, thus suggesting the frequency of updates to each layer of information. With regular analysis of changes in the VOA records at Line Entry level, it may be feasible to specify subsets of premises or Line Description/Room Use samples that require updating. This would negate the need for a major programme of surveys. Other information sources could be used to identify changes in patterns of equipment use, to aid the targeting of sample subsets.

For example, the Stuff Layer changes most frequently, indicating that this Layer of information requires accurate updating more than other Layers, i.e. more frequent surveys. If surveys of the equipment/appliance contents of premises are to be carried out, it is logical to record the activity happening in the space that contains these at the same time, keeping data applicable to VOA Line Descriptions up-to-date.

The effects of interventions may be seen in a temporal light, also. This is particularly so, when seeking to give priority to energy reduction interventions with a rapid effect.

In such a case interventions affecting premises, rather than buildings, are likely to take precedence – due to the faster rate of change. Alterations in internal gains would require adjustments to be made to HVAC treatment of spaces, with consequent changes in overall energy consumption for the premises and building. Also, it is possibly easier to instigate operational changes – namely at the premises level – than alterations to the other Layers of Change: Services, Skin, Structure and Site.

The audit trail of the SHU datasets (or subsequent accessible datasets) allows energy consumption interventions to be assessed right down to the scale of individual types of equipment and appliance. With this equipment held within a structured model of the stock, buildings, premises, Line Descriptions, and equipment taxonomy, it would be possible to better understand how the various aspects of any intervention would interact at each Layer of Change and level of detail.

6.4.2 Improvements to Valuation Office Agency Datasets

In terms of the Valuation Office Agency (VOA) datasets, the single most beneficial improvement would be if the VOA surveyors confined Line Descriptions to those used in Accommodation Use Codes, or a slightly expanded range of these. This would make the filtering of Line Descriptions much simpler, though there would still be a few Line Descriptions that would not be properly identified. The ideal situation would be a set of Accommodation Use Codes that encompassed, as precisely and accurately as would be reasonable, all the activities that occur in the subdivisions of the floorspace of UK non-domestic premises. A further improvement would be the recording of areas used for non-rateable uses, such as stairwells, toilets and so forth.

Adherence to the VOA's own stated practices of how the Special Category codes, Primary Descriptions and Primary Description codes are related, would also remove much of the ambiguity of the actual overall use of premises. This would be likely to make the VOA's own work easier, too, due to improved standardisation of space description. However, each of these recommendations should be considered in the light of the principal function of the VOA, which is to gather information to allow the accurate valuation of premises for taxation purposes, not to gather information for building stock energy modelling.

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Appendices

Appendix A

The lighting appliances in the SHU samples were updated according to the following.

Table Appendix A.1: SHU lighting updates.

Original data				**Updated data**				
Itemcode	**Description**	**Calcwatts**	**Calcloadfactor**	**Itemcode Update**	**Description Update**	**CalcWatts Update**	**Calcloadfactor Update**	**Quantity Update**
f2	26mm Fluor, 2 foot	15	1.2	f2tri	T8 Fluor, 2 foot, Triphosphor	18	1.2	
f2	26mm Fluor, 2 foot	18	1.2	f2tri	T8 Fluor, 2 foot, Triphosphor	18	1.2	
f2	26mm Fluor, 2 foot	18	0.5	f2tri	T8 Fluor, 2 foot, Triphosphor	18	0.5	
f2	26mm Fluor, 2 foot	20	1.2	f2tri	T8 Fluor, 2 foot, Triphosphor	18	1.2	
f2	26mm Fluor, 2 foot	36	1.2	f2tri	T8 Fluor, 2 foot, Triphosphor	18	1.2	
f2l	38mm Fluor, 2 foot	20	1.4	f2tri	T8 Fluor, 2 foot, Triphosphor	18	1.05	
f3	26mm Fluor, 3 foot	27	1.27	f3tri	T8 Fluor, 3 foot, Triphosphor	30	1.27	
f3	26mm Fluor, 3 foot	30	1.27	f3tri	T8 Fluor, 3 foot, Triphosphor	30	1.27	
f3	26mm Fluor, 3 foot	36	1.27	f3tri	T8 Fluor, 3 foot, Triphosphor	30	1.27	
f3	26mm Fluor, 3 foot	40	1.27	f3tri	T8 Fluor, 3 foot, Triphosphor	30	1.27	
f3l	38mm Fluor, 3 foot	30	1.2	f3tri	T8 Fluor, 3 foot, Triphosphor	30	1.05	
f4	26mm Fluor, 4 foot	15	1.25	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.25	
f4	26mm Fluor, 4 foot	20	1.25	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.25	
f4	26mm Fluor, 4 foot	30	1.25	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.25	
f4	26mm Fluor, 4 foot	36	1.25	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.25	
f4	26mm Fluor, 4 foot	38	1.25	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.25	
f4	26mm Fluor, 4 foot	40	1.25	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.25	
f4	26mm Fluor, 4 foot	58	1.25	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.25	
f4l	38mm Fluor, 4 foot	36	1.2	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.05	
f4l	38mm Fluor, 4 foot	40	1.2	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.05	
f4l	38mm Fluor, 4 foot	52	1.2	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.05	
f5	26mm Fluor, 5 foot	0	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.2	
f5	26mm Fluor, 5 foot	18	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.2	
f5	26mm Fluor, 5 foot	36	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.2	
f5	26mm Fluor, 5 foot	58	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.2	
f5	26mm Fluor, 5 foot	58	1	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1	
f5	26mm Fluor, 5 foot	58	0.5	f5tri	T8 Fluor, 5 foot, Triphosphor	58	0.5	
f5	26mm Fluor, 5 foot	60	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.2	
f5	26mm Fluor, 5 foot	63	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.2	
f5	26mm Fluor, 5 foot	65	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.2	
f5	26mm Fluor, 5 foot	70	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.2	
f5	26mm Fluor, 5 foot	75	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.2	

f5	26mm Fluor, 5 foot	79	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.2	
f5l	38mm Fluor, 5 foot	36	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.05	
f5l	38mm Fluor, 5 foot	65	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.05	
f5l	38mm Fluor, 5 foot	77	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.05	
f5l	38mm Fluor, 5 foot	80	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.05	
f5l	38mm Fluor, 5 foot	85	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.05	
f5l	38mm Fluor, 5 foot	90	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.05	
f5l	38mm Fluor, 5 foot	di	1.2	f5tri	T8 Fluor, 5 foot, Triphosphor	58	1.05	
f6	26mm Fluor, 6 foot	12	1.17	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.17	
f6	26mm Fluor, 6 foot	50	1.17	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.17	
f6	26mm Fluor, 6 foot	70	1.17	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.17	
f6	26mm Fluor, 6 foot	70	0.5	f6tri	T8 Fluor, 6 foot, Triphosphor	70	0.5	
f6	26mm Fluor, 6 foot	75	1.17	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.17	
f6	26mm Fluor, 6 foot	80	1.17	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.17	
f6l	38mm Fluor, 6 foot	65	1.16	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.05	
f6l	38mm Fluor, 6 foot	75	1.16	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.05	
f6l	38mm Fluor, 6 foot	80	1.16	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.05	
f6l	38mm Fluor, 6 foot	80	0.9	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.05	
f6l	38mm Fluor, 6 foot	85	1.16	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.05	
f6l	38mm Fluor, 6 foot	90	1.16	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.05	
f6l	38mm Fluor, 6 foot	100	1.16	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.05	
f6l/72	38mm Fluor, 6 foot, 72W	72	1.16	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.05	
f7	26mm Fluor, 7 foot	90	1.15	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.15	
f7l	38mm Fluor, 7 foot	100	1.15	f6tri	T8 Fluor, 6 foot, Triphosphor	70	1.05	
f8	26mm Fluor, 8 foot	70	1.15	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.15	x 2
f8	26mm Fluor, 8 foot	75	1.15	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.15	x 2
f8	26mm Fluor, 8 foot	85	1.15	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.15	x 2
f8	26mm Fluor, 8 foot	100	1.15	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.15	x 2
f8	26mm Fluor, 8 foot	125	1.15	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.15	x 2
f8	26mm Fluor, 8 foot	2000	1.15	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.15	x 2
f8/125	38mm Fluor, 8 foot, 125W	125	1.12	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.12	x 2
f8l	38mm Fluor, 8 foot	85	1.12	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.05	x 2
f8l	38mm Fluor, 8 foot	100	1.12	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.05	x 2
f8l	38mm Fluor, 8 foot	120	1.12	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.05	x 2
f8l	38mm Fluor, 8 foot	125	1.12	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.05	x 2
f8l	38mm Fluor, 8 foot	138	1.12	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.05	x 2
f8l	38mm Fluor, 8 foot	150	1.12	f4tri	T8 Fluor, 4 foot, Triphosphor	36	1.05	x 2
t100	Tungsten Filament 100 W	100	1	cfli20	Cmpct fluor with integral cntrl gear 20W	20	1	
t120	Tungsten Filament 120 W	120	1	cfli20	Cmpct fluor with integral cntrl gear 20W	20	1	
t120	Tungsten Filament 120 W	125	1	cfli20	Cmpct fluor with integral cntrl gear 20W	20	1	
t150	Tungsten Filament 150 W	150	1	cfli20	Cmpct fluor with integral cntrl gear 20W	20	1	
t25	Tungsten Filament 25 W	25	1	cfli7	Cmpct fluor with integral cntrl gear 7W	7	1	
t30	Tungsten Filament 30 W	30	1	cfli7	Cmpct fluor with integral cntrl gear 7W	7	1	
t30	Tungsten Filament 30 W	30	1	cfli7	Cmpct fluor with integral cntrl gear 7W	7	1	

t38	Tungsten Filament 38 W	38	1	cfli9	Cmpct fluor with integral cntrl gear 9W	9	1	
t40	Tungsten Filament 40 W	40	1	cfli9	Cmpct fluor with integral cntrl gear 9W	9	1	
t50	Tungsten Filament 50 W	50	1	cfli11	Cmpct fluor with integral cntrl gear 11W	11	1	
t50	Tungsten Filament 50 W	50	1	cfli11	Cmpct fluor with integral cntrl gear 11W	11	1	
t60	Tungsten Filament 60 W	60	1	cfli15	Cmpct fluor with integral cntrl gear 15W	15	1	
t75	Tungsten light 75W	75	1	cfli15	Cmpct fluor with integral cntrl gear 15W	15	1	
t80	Tungsten Filament 80 W	80	1	cfli18	Cmpct fluor with integral cntrl gear 18W	18	1	

Appendix B

SHU space use analyses. See attached CD-ROM

Appendix C

SHU Energy Intensities. See attached CD-ROM

Appendix D

SHU End Uses analyses. See attached CD-ROM

Appendix E

SHU Used For Groups analyses. See attached CD-ROM

Appendix F

Table of filtered Primary Description codes, found in the Leicester City Rating List and SMV. Note that the descriptions have been rationalised, for simplicity.

PD Code	Description	PD Code	Description
CG1	Vehicle Repair Workshops & Garages	CW1	Land Used For Storage
CG2	Bus Garage	CW2	Storage Depots
CG3	Garage	CW3	Stores Within/Part of Specialist Property
CL1	wine Bar	CX	Various Commercial
CL2	Clubs & Institutions	EN1	Nursery
CO	Office	EP	Public and Independent Schools
CP	Car Park	EX	Various Educational
CP1	Car Park Space	IF	Factory
CR	Restaurant	IF2	Works
CR1	Café	IF3	Workshop
CS	Shop	IX	Various Industrial
CS1	Bank	LC	Community Day Centres
CS10	Retail Warehouses and Foodstores	LC1	Clubhouses
CS2	Betting Offices	LC3	Public Halls
CS3	Hairdressing/Beauty Salons	LT1	Amusement Arcades
CS4	Kiosks Within/Part of Specialist Property	LX	Various Leisure
CS5	Launderette	MH	Surgery
CS6	Post Offices	MH1	Health Centre
CS7	Showrooms	ML	Offices Within/Part of Specialist Property
CS9	Large Shop	MX	Various (mostly) Municipal
CW	Warehouse		

Appendix G

Table of search strings used to identify Line Descriptions. See Section 4.6.3 Identifying and Rationalising Line Descriptions

In Table Appendix G.1 and Table Appendix G.2, pale blue cells contain the descriptions attached to Accommodation Use Codes (AUC). Yellow cells are the additional space use descriptions used to identify non-standard Line Descriptions. Green cells require positive results and salmon cells require negative results.

Table Appendix G.1 shows the cell and string searches that require positive results, i.e. "IS=" string searches.

Table Appendix G.2 shows the string searches that require negative results (where required) for the same line Descriptions shown in Table Appendix G.1, i.e. "ISNOT=" string searches.

Both tables are ranked according to whether the Line Description is an AUC, then by the summed areas for that Line Description, within the test area Summary Valuation database.

Where an underscore ("_") appears in a cell, it represents a space in the search string.

Table Appendix G.1: VOA Line Description identification cell matches and string searches, for positive results.

	Stage 1	**Stage 2**					
Search Line Description	**IS = Cell**	**IS = Cell**	**IS = String**				
Production Area	Production Area		Production Area				
Warehouse	Warehouse		Warehouse				
Office	Office		Office				
Workshop	Workshop		Workshop				
Internal storage	Internal storage		Internal storage				
All main areas	All main areas		All main areas				
Retail Zone A	Retail Zone A		Retail zone A				
Retail Zone B	Retail Zone B		Retail zone B				

Store	Store		Store				
Ground Floor Sales	Ground Floor Sales		Ground Floor Sales				
Food Processing Areas	Food Processing Areas		Food Processing Areas				
Retail Area	Retail Area		Retail Area				
Showroom	Showroom		Showroom				
Retail Zone C	Retail Zone C		Retail Zone C				
External storage	External storage		External storage				
Remaining Retail Zone	Remaining Retail Zone		Remaining Retail Zone				
Works office	Works office		Works office				
Kitchen	Kitchen		Kitchen				
Rough surfaced, fenced land	Rough surfaced, fenced land		Rough surfaced, fenced land				
Garage	Garage		Garage				
Loading Bay	Loading Bay		Loading Bay				
Restaurant	Restaurant		Restaurant				
Unsurfaced, fenced land	Unsurfaced, fenced land		Unsurfaced, fenced land				
Lounge	Lounge		Lounge				
Canopy	Canopy		canop				
Hard Surfaced, fenced land	Hard Surfaced, fenced land		Hard Surfaced, fenced land				
Plant room	Plant room		Plant				
Mess/Staff room	Mess/Staff room		Mess/Staff room				
Nursery	Nursery		Nursery				
Parking Space(s)	Parking Space(s)		Parking Space(s)				
Chill store	Chill store		Chill store				
Canteen	Canteen		Canteen				
Bar	Bar		Bar				
Public toilets	Public toilets		Public toilets				
Reception / Entrance	Reception / Entrance		Reception / Entrance				
Surgery	Surgery		Surgery				
Unclassified area	Unclassified area		Unclassified area				
Storage	Storage		Storage				
Classroom	Classroom		Classroom				

Cold store	Cold store		Cold store				
Staff toilets	Staff toilets		Staff toilets				
Computer room	Computer room		Comput	Server room			
Banking Hall	Banking Hall		Banking Hall				
Committee Room	Committee Room		Committee Room				
Changing room	Changing room		Changing room				
Hard Surfaced, unfenced land	Hard Surfaced, unfenced land		Hard Surfaced, unfenced land				
Laboratory	Laboratory		Laborator				
Locker room	Locker room		Locker room				
Shed	Shed		Shed				
Cells	Cells		Cells				
Function Room	Function Room		Function Room				
Portable Building	Portable Building		Portable Building				
Gatehouse	Gatehouse		Gatehouse				
Atrium	Atrium		Atrium				
Covered Area	Covered Area		Covered Area				
Showers	Showers		Showers				
First floor sales	First floor sales		First floor sales				
Retail Zone D	Retail Zone D		Retail Zone D				
Boardroom	Boardroom		Boardroom				
Glasshouse	Glasshouse		Glasshouse				
Abattoir Lairage	Abattoir Lairage		Abattoir Lairage				
Amusement Arcade	Amusement Arcade		Amusement Arcade				
Ancillary Office	Ancillary Office		Ancillary Office				
Bicycle Parking Space(s)	Bicycle Parking Space(s)		Bicycle Parking Space(s)				
Coach Parking Space(s)	Coach Parking Space(s)		Coach Parking Space(s)				
Disabled Parking Space(s)	Disabled Parking Space(s)		Disabled Parking Space(s)				
Filling Station shop	Filling Station shop		Filling Station shop				
First floor production area	First floor production area		First floor production area				

Health Centre	Health Centre		Health Centre				
Hi Tech Accommodation	Hi Tech Accommodation		Hi Tech Accommodation				
Lift Shaft	Lift Shaft		Lift Shaft				
Lock Up Garage	Lock Up Garage		Lock Up Garage				
Lorry/Truck Parking Space(s)	Lorry/Truck Parking Space(s)		Lorry/Truck Parking Space(s)				
Lower Ground Floor sales	Lower Ground Floor sales		Lower Ground Floor sales				
Misc Area	Misc Area		Misc Area				
Motorbike Parking Space(s)	Motorbike Parking Space(s)		Motorbike Parking Space(s)				
Other Retail Zone	Other Retail Zone		Other Retail Zone				
Outdoor display/seating area	Outdoor display/seating area		Outdoor display/seating area				
Parking Area	Parking Area		Parking Area				
Retail Zone E	Retail Zone E		Retail Zone E				
Retail Zone F	Retail Zone F		Retail Zone F				
Rough surfaced, unfenced land	Rough surfaced, unfenced land		Rough surfaced, unfenced land				
Sales Display area	Sales Display area		Sales Display area				
Strongroom	Strongroom		Strongroom				
Unsurfaced, unfenced land	Unsurfaced, unfenced land		Unsurfaced, unfenced land				
Hall			Hall				
Boiler			Boiler				
Meeting room			Meeting room				
Lift motor			Lift motor				
_shop			_shop				
Assembly			assembly				
Vehicle Repair Workshop			Vehicle Repair Workshop				
Sorting Office			Sorting Office				
Retail warehouse			Retail warehouse				
_site			_site				
_Land			_Land				
Sales area			Sales area				

Sales floor			Sales floor				
Vehicle service			Vehicle service				
Garden centre			Garden centre				
Reception			reception				
External			External				
Compound			Compound				
Packing			Packing				
Community			Community				
Studio			Studio				
Dance Studio			Dance Studio				
Call Centre			Call Centre				
Beer cellar			Beer cellar				
Cellar			Cellar				
Consulting			Consulting				
Surgeries			Surgeries				
Games room			Games room				
Salon			Salon				
Foundry			Foundry				
Billiard/Pool/Snooker Hall/Room		snooker	billiard	snooker hall	snooker room	pool hall	pool room
Bakery			Bakery				
Playroom			Playroom				
Bodyshop			Bodyshop				
Printing			Printing				
Workshop studio			Workshop studio				
Treatment room			Treatment room				
Ancilliary Office			Ancilliary Office				
Club			club				
sales etc overall			sales etc overall				
training			training				
process			process				

gymnasium			gym				
service bay			service bay				
tyre			tyre				
_production			_production				
conference			conference				
Lecture			Lecture				
café			café				
teaching			teaching				
prod.			prod.				
Scrapyard			Scrapyard				
valeting			valeting				
fitness			fitness				
stock room			stock				
Yard			_yard				
Production		Production					

Table Appendix G.2: VOA Line Description identification cell matches and string searches, for negative results.

Stage 2						
Search Line Description	**IS NOT = Cell**		**IS NOT = String**			
Production Area	first floor production area					
Warehouse	retail warehouse					
Office	sorting office		works office	ancillary office	ancilliary office	
Workshop	vehicle repair workshop	workshop studio				
Internal storage						
All main areas						
Retail Zone A						
Retail Zone B						
Store			storey	cold		
Ground Floor Sales			lower ground floor sales			
Food Processing Areas						
Retail Area						
Showroom						
Retail Zone C						
External storage						
Remaining Retail Zone						
Works office						
Kitchen						
Rough surfaced, fenced land						
Garage			lock up garage			
Loading Bay						

Restaurant						
Unsurfaced, fenced land						
Lounge						
Canopy						
Hard Surfaced, fenced land						
Plant room						
Mess/Staff room						
Nursery						
Parking Space(s)						
Chill store						
Canteen						
Bar						
Public toilets						
Reception / Entrance						
Surgery						
Unclassified area						
Storage	Internal storage		internal storage			
Classroom						
Cold store						
Staff toilets						
Computer room						
Banking Hall	hall					
Committee Room						
Changing room						
Hard Surfaced, unfenced land						
Laboratory						
Locker room						
Shed			refurbished			
Cells						
Function Room						
Portable Building						

Gatehouse						
Atrium						
Covered Area						
Showers						
First floor sales						
Retail Zone D						
Boardroom						
Glasshouse						
Abattoir Lairage						
Amusement Arcade						
Ancillary Office						
Bicycle Parking Space(s)						
Coach Parking Space(s)						
Disabled Parking Space(s)						
Filling Station shop						
First floor production area						
Health Centre						
Hi Tech Accommodation						
Lift Shaft						
Lock Up Garage						
Lorry/Truck Parking Space(s)						
Lower Ground Floor sales						
Misc Area						
Motorbike Parking Space(s)						
Other Retail Zone						
Outdoor display/seating area						
Parking Area						
Retail Zone E						
Retail Zone F						
Rough surfaced, unfenced land						
Sales Display area						
Strongroom						

Unsurfaced, unfenced land						
Hall			Banking Hall	Snooker	Pool	Assembly Hall
Boiler						
Meeting room						
Lift motor						
_shop	filling station shop					
Assembly						
Vehicle Repair Workshop						
Sorting Office						
Retail warehouse						
_site						
_Land						
Sales area						
Sales floor						
Vehicle service						
Garden centre						
Reception						
External			external storage			
Compound						
Packing						
Community						
Studio			dance studio	workshop studio	fitness studio	
Dance Studio						
Call Centre						
Beer cellar						
Cellar	Beer cellar					
Consulting						
Surgeries						
Games room						
Salon						

Foundry						
Billiard/Pool/Snooker Hall/Room						
Bakery						
Playroom			nursery			
Bodyshop						
Printing						
Workshop studio						
Treatment room						
Ancilliary Office						
Club						
sales etc overall						
training						
process			food processing area			
gymnasium						
service bay			vehicle service	workshop		
tyre						
_production						
conference						
Lecture						
café						
teaching						
prod.						
Scrapyard						
valeting						
fitness						
stock room						
Yard						
Production						

Table Appendix G.3: Conversion factor for NIA to GIA applied to Line Entry floor areas.

PDCode	NIA:GIA Factor		PDCode	NIA:GIA Factor
CG1	1		CW1 (external)	0
CG2	1		CW2	1
CG3	1.2		CW3	1
CL1	1		CX (external)	0
CL2	1.2		CX	1.2
CO	1.2		CX	1
CP1	1		EN1	1
CP	1		EP	1
CR	1.2		EX	1.2
CR1	1.2		IF	1
CS	1.2		IF2	1
CS10	1.1		IF3	1
CS1	1.2		IX	1
CS2	1.2		LC1	1.2
CS3	1.2		LC3	1.2
CS4	1.2		LC	1.2
CS5	1.2		LT1	1.2
CS6	1.2		LX	1.1
CS7	1.2		MH1	1.2
CS9	1.1		MH	1.2
CS	1.1		ML	1.2
CW	1		MX	1.2

Appendix H

Table Appendix H.1 shows how appliances were allocated to a Used For group, according to their Used For code within the SHU datasets. Note that a three level coding system is used to categorise each item. A key to the UFCodeGroup is given in Table Appendix H.2, below.

Table Appendix H.1: Categorisation of appliance Used For codes into Used For Code Groups.

Usedforcode	Usedfordesc	Usedforeg	UsedForDesc	UFCodeGroup	UFCode1	UFCode2	UFCode3	UFFullCode
acr	air circulation within room	desk fans, ceiling fans	HVAC space ventilation	11	H	S	Vent	HSVent
aud	audiovisual	PA systems, musak	other	16	Z	AV		ZAV
b/f	balancing figure		balancing figure	1	X			X
c	computing	PCs	office work	15	O	Comp		OComp
cfd	chilled food and drink	office fridges, shop sales fridges, restaurant fridges	refrigeration food chilled	10	R	Food	Chill	RFoodChill
cfm	catering - food manufacture	bakeries	process food manufacturing	17	P	Food		PFood
cg	catering - general	catering equipment not used exclusively for self, staff or puplic.	catering general	2	C	Gen		CGen
cln	cleaning	office vacuum cleaners	facilities cleaning	9	F	Clean		FClean
cop	copying	photocopying	office work	15	O	Print		OPrint
cp	catering - public	restaurants	catering commercial	2	C	Public		CPublic
cs	catering - self	office microwave	catering non-commercial	2	C	NonPublic		CNonPublic

cst	catering - staff	staff canteens	catering non-commercial	2	C	NonPublic		CNonPublic
dhw	domestic hot water	immersion heater	DHW	5	D			D
di	display illumination	shop windows, display cabinets	sales display	19	I	Sal	Disp	ISalDisp
dry	drying	clothes drying, hand drying	drying	6	Z	Dry		ZDry
dsc	cooling function of dual heating/cooling device		HVAC space cooling	11	H	S	Cool	HSCool
dse	direct supply/extract of air	expelair etc	HVAC space ventilation	11	H	S	Vent	HSVent
dsh	heating function of dual heating/cooling device		HVAC space heating	11	H	S	Heat	HSHeat
ec	eqipment cooling	cooling computer rooms	cooling of equipment	4	P	Equip	Cool	PEquipCool
ed	educational		education	7	L			L
ei	emergency illumination		illumination emergency	12	I	Em		IEm
ent	entertainment		entertainment	8	E			E
exi	external illumination	car park lighting	illumination external	12	I	Extnl		IExtnl
ff	frozen food		refrigeration food frozen	10	R	Food	Froz	RFoodFroz
fl	flood lighting		illumination flood	12	I	Flood		IFlood
gi	general illumination	lights etc	illumination general	12	I	Gen		IGen
h	humidity control		HVAC space humidity	11	H	S	Humid	HSHumid

hdp	hot drinks preparation	kettles, drinks machines	catering general	2	C	Gen		CGen
hvacc	HVAC controls		HVAC controls	11	H	Ctrl		HCtrl
laun	laundry		laundry	13	Z	Laun		ZLaun
lr	laboratory research	water baths	process laboratory	17	P	Lab		PLab
lsp	large scale printing		process	17	P	Print		PPrint
mada	moving air through ducts - all year round		HVAC space ventilation	11	H	S	Vent	HSVent
mads	moving air through ducts - summer		HVAC space ventilation	11	H	S	Vent	HSVent
madw	moving air through ducts - winter		HVAC space ventilation	11	H	S	Vent	HSVent
main	maintenance		facilities maintenance	9	F	Maint		FMaint
mg	moving goods	goods lifts	moving goods	14	T	Goods		TGoods
misco	misc. office		office work	15	O	Misc		OMisc
mp	moving people	lifts, escalators	moving people	14	T	Ppl		TPpl
oth	other		other	16	Z			Z
ph	photographic	film developing	process photographic	17	P	Photo		PPhoto
prin	printing	office laser printer	office work	15	O	Print		OPrint
proc	process		process	17	P	Gen		PGen
sal	sales	tills, checkout scales, eftpos machines	sales	19	S	Gen		SGen
sc	space cooling		HVAC space cooling	11	H	S	Cool	HSCool
sec	security	security surveylance	other	16	Z	Sec		ZSec
sh	space heating		HVAC space heating	11	H	S	Heat	HSHeat
shdhw	space heating and DHW	boiler	HVAC space heating and DHW	11	H	S	Heat	HSHeat

si	sign illumination	shop front name signs	illumination sign	12	I	Sign		ISign
spec	specialist uses	dentists' machinery	special	20	Y			Y
t	telecommunications	telephones	telecoms	21	O	Tel		OTel
ti	task illumination	task lighting	illumination task	12	I	Task		ITask
uk	unknown		unknown	22	U			U
wca	water circulation - all year round	dhw circulation	HVAC pumps water circulation	18	H	Pump		HPump
wcs	water circulation - summer	cooling water circulation	HVAC pumps chilled water circulation	18	H	Pump	Cool	HPumpCool
wcw	water circulation - winter	heating water circulation	HVAC pumps heated water circulation	18	H	Pump	Heat	HPumpHeat
wpb	water pressure boosting		HVAC pumps pressure boosters	18	H	Pump	Pres	HPumpPres

Table Appendix H.2; Key to UsedForGroupCodes in Table Appendix H.1.

UFGroupCode	UsedForGroup
1	balancing figure
2	catering
3	other
4	DHW
5	learning
6	entertainment
7	facilities
8	refrigeration
9	HVAC
10	illumination
11	transport
12	office work
13	process
14	pumps
15	sales
16	specialist
17	telecoms
18	unknown

The words in **bold** type are the space use categories and the plain text words are the New Line Descriptions (LineDescNew)

Note that some LineDescNew are preceded by a Primary Description code. These combinations are specific to the space use category. For example, CS_shop is sales space in Shop premises; whereas IF3_shop is a production area in Workshop premises.

Table Appendix H.3: New Line Descriptions allocated to space use classes.

Catering, eating, drinking	**other**	**entertainment/leisure**	**support space**	**refrigeration**	**HVAC**	**storage**
Bar	cells	Billiard/Pool/Snooker Hall/Room	atrium	beer cellar	boiler	Cellar
Cafe	classroom	Club	changing room	chill store	plant room	internal storage
Canteen	Consulting	community	Gatehouse	cold store		stock room
kitchen	Health Centre	conference	locker room			storage
lounge	lecture	Dance studio	Mess/Staff room			store
restaurant	Nursery	fitness	Public toilets			stores
CR1_shop	Playroom	Function room	reception			strongroom
	portable building	Games room	reception / entrance			warehouse
	Salon	gymnasium	Showers			
	Surgeries	CL2Hall	Staff toilets			
	Surgery	COHall				
	teaching	CSHall				
	training	CWHall				
	Treatment room	LC1Hall				
		LC3Hall				
		LCHall				

office work, meetings, computing	Process/workshops	sales	area valued on an overall basis
Ancillary Office	_production	Banking Hall	All Main areas
boardroom	Assembly	First floor sales	Sales etc overall
call centre	Bakery	Garden centre	
Committee room	bodyshop	Ground floor sales	
computer room	Food processing areas	Remaining retail zone	
Computer room/Server room	Foundry	Retail area	
Meeting room	Laboratory	Retail warehouse	
office	Packing	Retail Zone A	
Studio	printing	Retail Zone B	
works office	process	Retail Zone C	
	prod.	Retail Zone D	
	production	Retail Zone E	
	production area	Sales area	
	service bay	Sales floor	
	Sorting Office	Showroom	
	tyre	CG3_shop	
	valeting	CO_shop	
	vehicle Repair Workshop	CR_shop	
	vehicle service	CS_shop	
	Workshop	ML_shop	
	Workshop studio		
	IFHall		
	IF2Hall		
	CG1_shop		
	IF_shop		
	IF2_shop		
	IF3_shop		

Appendix I

Table Appendix I.4, below, shows the matrix of the SHU:VOA Map, used for applying SHU Room Use and Primary Description code combinations to VOA Line Description and Primary Description code combinations, that describe the use of space in premises.

KEY:

% of Total Area of SMV (1): the total area of the indentified new Line Description (LineDescNew) expressed as a percentage of the total are of the sum of Line Entry areas in the SMV database.

Sum of Area: the summed Line Entry areas for the LineDescNew.

PDCode in Rating List: The Primary Description code held in the Rating List.

SumOfArea: the summed areas for the LineDescNew and PD code combination

% of Total Area of SMV (2): the total area of the indentified LineDescNew and PD code combination, expressed as a percentage of the total are of the sum of Line Entry areas in the SMV database.

Location Code: A code describing the location of the LineDescNew, in terms of the applicability of internal gains. 1 = internal; 2 = external; 3 = may be internal or external; 4 = cannot be determined.

PD Code in SHU: The Primary Description code from which the SHU Room Uses (SHU RmUse) are sourced.

SHU RmUse 1 to 7: the SHU Room Use that provides the electricity consumption and use profiles for application to the LineDescNew.

Colour codes: columns headed grey are from the VOA datasets; columns headed white are from the SHU analyses. Blue cells indicate the the LineDescNew is a description attached to a VOA Accommodation Use Code (AUC). Cells coloured salmon are additional LineDescNew, used to identify more than the standard AUCs. Cells coloured green indicate LineDescNew that are considered to be external; yellow internal or external; pink unknown. Grey cells indicate Room Uses generated from subsets of the SHU data, used to describe specific LineDescNew. Red cells indicate LineDescNew that cannot currently be identified with accuracy, but the LineDescNew is believed to not properly represent the activity performed in the Line Description of particular premises.

Table Appendix I.4: SHU:VOA Map.

% of Total Area of SMV (1)	SumOfArea	LineDescNew	PDCode in Rating List	SumOfArea	% of Total Area of SMV (2)	LocationCode	PD Code in SHU	SHU RmUse1	SHU RmUse2	SHU RmUse3	SHU RmUse4	SHU RmUse5	SHU RmUse6	SHU RmUse7
22.2	915455	Production Area	CG1	424	0.010	1	CG1	carser						
		Production Area	CG2	3337	0.081	1	CG1	carser						
		Production Area	CO	275	0.007	1	IF3	proc						
		Production Area	CW	20478	0.497	1	IF3	proc						
		Production Area	CW3	2612	0.063	1	IF3	proc						
		Production Area	IF	831615	20.175	1	IF	proc						
		Production Area	IF2	14542	0.353	1	IF	proc						
		Production Area	IF3	41972	1.018	1	IF3	proc						
		Production Area	LC	200	0.005	1	IF3	proc						
17.4	715882	Warehouse	CG1	487	0.012	1	CG1	store						

		Warehouse	CG3	465	0.011	1	CG1	store							
		Warehouse	CO	847	0.021	1	CO	store							
		Warehouse	CS	1515	0.037	1	CS	store							
		Warehouse	CS10	1637	0.040	1	CS	store							
		Warehouse	CS7	1239	0.030	1	CS7	store							
		Warehouse	CW	595836	14.455	1	CW	store							
		Warehouse	CW3	2554	0.062	1	CW	store							
		Warehouse	IF	99518	2.414	1	IF	store							
		Warehouse	IF2	4458	0.108	1	IF	store							
		Warehouse	IF3	7178	0.174	1	IF3	store							
		Warehouse	MH	148	0.004	1	CO	store							
16.3	672506	Office	CG1	1912	0.046	1	CG1	off	prin	mtg	teach	circ			
		Office	CG2	2545	0.062	1	CG1	off	prin	mtg	teach	circ			
		Office	CG3	7929	0.192	1	CG1	off	prin	mtg	teach	circ			
		Office	CL1	13	0.000	1	CL	off							
		Office	CL2	1275	0.031	1	CS	off							
		Office	CO	388218	9.418	1	CO	off	prin	sec	mtg	cmp	teach	circ	
		Office	CP	70	0.002	1	GENERIC	off	prin	sec	mtg				
		Office	CR	697	0.017	1	CR	off	teach						
		Office	CR1	62	0.002	1	CR	off	teach						
		Office	CS	21761	0.528	1	CS	off	prin	sec	mtg	cmp	teach		
		Office	CS1	5807	0.141	1	CS1	off	prin	sec	mtg	cmp	teach		
		Office	CS10	1321	0.032	1	CS	off	prin	sec	mtg	cmp	teach		
		Office	CS2	344	0.008	1	CS	off	prin	sec	mtg	cmp	teach		
		Office	CS3	126	0.003	1	CS	off	prin	sec	mtg	cmp	teach		
		Office	CS6	987	0.024	1	CS6	off	prin	mtg	cmp	teach			
		Office	CS7	457	0.011	1	CS7	off	prin	cmp	circ				
		Office	CW	86262	2.093	1	CW	off	prin	mtg	cmp	teach	circ		
		Office	CW1	51	0.001	1	CW	off	prin	mtg	cmp	teach	circ		
		Office	CW2	1929	0.047	1	CW	off	prin	mtg	cmp	teach	circ		
		Office	CW3	1981	0.048	1	CW	off	prin	mtg	cmp	teach	circ		
		Office	CX	827	0.020	1	GENERIC	off	prin	sec	mtg	cmp	teach		

		Office	EN1	994	0.024	1	EL	off	prin	mtg	cmp				
		Office	EP	1072	0.026	1	GENERIC	off	prin	sec	mtg	cmp			
		Office	EX	153	0.004	1	GENERIC	off	prin	sec	mtg	cmp			
		Office	IF	109984	2.668	1	IF	off	prin	mtg	cmp	teach	graph	circ	
		Office	IF2	7888	0.191	1	IF	off	prin	mtg	cmp	teach	circ		
		Office	IF3	16868	0.409	1	IF3	off	prin	graph	circ	ph			
		Office	LC	2114	0.051	1	LC1	off	mtg						
		Office	LC1	10	0.000	1	LC1	off	mtg						
		Office	LC3	225	0.005	1	LC1	off	mtg						
		Office	LT1	49	0.001	1	CS	off	prin	sec	mtg	cmp	teach		
		Office	LX	59	0.001	1	GENERIC	off	prin	sec	mtg	cmp			
		Office	MH	2806	0.068	1	CO	off	prin	mtg	circ				
		Office	MH1	39	0.001	1	CO	off	prin	mtg	circ				
		Office	ML	5673	0.138	1	CO	off	prin	sec	mtg	cmp	teach	circ	
6.2	254933	Workshop	CG1	20449	0.496	1	CG1	carser							
		Workshop	CG2	6687	0.162	1	CG1	carser							
		Workshop	CG3	19707	0.478	1	CG1	carser							
		Workshop	CO	1854	0.045	1	GENERIC	worksh							
		Workshop	CP	662	0.016	1	GENERIC	worksh							
		Workshop	CS	3488	0.085	1	CS	worksh							
		Workshop	CS10	179	0.004	1	CS	worksh							
		Workshop	CS7	1023	0.025	1	CS7	worksh							
		Workshop	CW	8208	0.199	1	GENERIC	worksh							
		Workshop	CW1	890	0.022	1	GENERIC	worksh							
		Workshop	CW2	985	0.024	1	GENERIC	worksh							
		Workshop	CW3	1630	0.040	1	GENERIC	worksh							
		Workshop	CX	59	0.001	1	GENERIC	worksh							
		Workshop	IF	90063	2.185	1	IF	worksh							
		Workshop	IF2	1591	0.039	1	IF	worksh							
		Workshop	IF3	96925	2.351	1	IF3	proc							
		Workshop	LC	350	0.008	1	LC1	worksh							
		Workshop	LC3	56	0.001	1	LC1	worksh							

		Workshop	MH	126	0.003	1	GENERIC	worksh						
5.4	224607	Internal storage	CG1	1529	0.037	1	CG1	store	spstore					
		Internal storage	CG2	2123	0.051	1	CG1	store	spstore					
		Internal storage	CG3	4168	0.101	1	CG1	store	spstore					
		Internal storage	CL1	175	0.004	1	CL	store	spstore					
		Internal storage	CL2	3073	0.075	1	CL	store	spstore					
		Internal storage	CO	16511	0.401	1	CO	store	spstore					
		Internal storage	CP	0	0.000	1	GENERIC	store	spstore	lib				
		Internal storage	CR	5559	0.135	1	CR	store	spstore					
		Internal storage	CR1	882	0.021	1	CR	store	spstore					
		Internal storage	CS	79294	1.924	1	CS	store	spstore					
		Internal storage	CS1	3647	0.088	1	CS1	store	spstore					
		Internal storage	CS10	866	0.021	1	CS	store	spstore					
		Internal storage	CS2	275	0.007	1	CS	store	spstore					
		Internal storage	CS3	694	0.017	1	CS	store	spstore					
		Internal storage	CS4	14	0.000	1	CS	store	spstore					
		Internal storage	CS5	63	0.002	1	CS	store	spstore					
		Internal storage	CS6	601	0.015	1	CS6	store	spstore					
		Internal storage	CS7	3220	0.078	1	CS7	store	spstore					
		Internal storage	CW	31473	0.764	1	CW	store	spstore					
		Internal storage	CW2	471	0.011	1	CW	store	spstore					
		Internal storage	CW3	2583	0.063	1	CW	store	spstore					
		Internal storage	CX	29	0.001	1	GENERIC	store	spstore					
		Internal storage	EN1	757	0.018	1	EL	store	spstore					
		Internal storage	EP	125	0.003	1	EL	store	spstore					
		Internal storage	EX	5	0.000	1	EL	store	spstore					
		Internal storage	IF	53476	1.297	1	IF	store	spstore					
		Internal storage	IF2	24	0.001	1	IF	store	spstore					
		Internal storage	IF3	8614	0.209	1	IF3	store	spstore					
		Internal storage	LC	1069	0.026	1	LC1	store	spstore					
		Internal storage	LC1	588	0.014	1	LC1	store	spstore					
		Internal storage	LC3	337	0.008	1	LC1	store	spstore					

		Internal storage	LT1	103	0.002	1	GENERIC	store	spstore					
		Internal storage	MH	994	0.024	1	GENERIC	store	spstore					
		Internal storage	ML	1227	0.030	1	GENERIC	store	spstore					
		Internal storage	MX	39	0.001	1	GENERIC	store	spstore					
3.8	155124	All main areas	CR	2170	0.053	1	CR	GENERIC						
		All main areas	CS	119370	2.896	1	CS	GENERIC						
		All main areas	CS9	33584	0.815	1	CS	GENERIC						
3.0	124152	Retail Zone A	CL1	52	0.001	1	GENERIC	sal						
		Retail Zone A	CO	1089	0.026	1	GENERIC	sal						
		Retail Zone A	CR	4111	0.100	1	GENERIC	sal						
		Retail Zone A	CR1	1138	0.028	1	GENERIC	sal						
		Retail Zone A	CS	109429	2.655	1	CS	sal						
		Retail Zone A	CS1	2738	0.066	1	CS1	profs						
		Retail Zone A	CS10	38	0.001	1	CS	sal						
		Retail Zone A	CS2	1533	0.037	1	CS	sal						
		Retail Zone A	CS3	2853	0.069	1	CS	sal						
		Retail Zone A	CS5	479	0.012	1	GENERIC	sal						
		Retail Zone A	CS6	136	0.003	1	CS6	profs						
		Retail Zone A	CS7	264	0.006	1	CS7	sal						
		Retail Zone A	CW3	23	0.001	1	CW	sal						
		Retail Zone A	IF3	68	0.002	1	GENERIC	sal						
		Retail Zone A	LT1	104	0.003	1	CS	sal						
		Retail Zone A	MH	98	0.002	1	GENERIC	sal						
2.5	101851	Store	CG1	1607	0.039	1	CG1	store	spstore					
		Store	CG2	612	0.015	1	CG1	store	spstore					
		Store	CG3	2241	0.054	1	CG1	store	spstore					
		Store	CL2	40	0.001	1	CL	store	spstore					
		Store	CO	6498	0.158	1	CO	store	spstore	lib				
		Store	CR	519	0.013	1	CR	store	spstore					
		Store	CR1	59	0.001	1	CR	store	spstore					
		Store	CS	2853	0.069	1	CS	store	spstore					
		Store	CS1	29	0.001	1	CS1	store	spstore					

		Store	CS3	67	0.002	1	GENERIC	store	spstore					
		Store	CS7	250	0.006	1	CS7	store	spstore					
		Store	CS9	248	0.006	1	GENERIC	store	spstore					
		Store	CW	25765	0.625	1	CW	store	spstore					
		Store	CW1	51	0.001	1	CW	store	spstore					
		Store	CW2	1069	0.026	1	CW	store	spstore					
		Store	CW3	23930	0.581	1	CW	store	spstore					
		Store	CX	602	0.015	1	GENERIC	store	spstore					
		Store	EN1	213	0.005	1	EL	store	spstore					
		Store	EP	941	0.023	1	EL	store	spstore					
		Store	IF	23419	0.568	1	IF	store	spstore					
		Store	IF2	1473	0.036	1	IF	store	spstore					
		Store	IF3	5070	0.123	1	IF3	store	spstore					
		Store	IX	3082	0.075	1	CW	store	spstore					
		Store	LC	67	0.002	1	LC1	store	spstore					
		Store	LC3	76	0.002	1	LC1	store	spstore					
		Store	LT1	191	0.005	1	GENERIC	store	spstore					
		Store	MH	452	0.011	1	GENERIC	store	spstore					
		Store	ML	428	0.010	1	GENERIC	store	spstore					
1.8	72321	Retail Zone B	CL1	36	0.001	1	GENERIC	sal						
		Retail Zone B	CO	581	0.014	1	GENERIC	sal						
		Retail Zone B	CR	3203	0.078	1	GENERIC	sal						
		Retail Zone B	CR1	597	0.014	1	GENERIC	sal						
		Retail Zone B	CS	62679	1.521	1	CS	sal						
		Retail Zone B	CS1	2337	0.057	1	CS1	profs						
		Retail Zone B	CS10	28	0.001	1	GENERIC	sal						
		Retail Zone B	CS2	946	0.023	1	CS	sal						
		Retail Zone B	CS3	1021	0.025	1	CS	sal						
		Retail Zone B	CS5	247	0.006	1	GENERIC	sal						
		Retail Zone B	CS6	180	0.004	1	CS6	profs						
		Retail Zone B	CS7	316	0.008	1	CS7	sal						
		Retail Zone B	CW3	12	0.000	1	CW	store						

		Retail Zone B	IF3	10	0.000	1	GENERIC	sal						
		Retail Zone B	LT1	66	0.002	1	CS	sal						
		Retail Zone B	MH	62	0.001	1	GENERIC	sal						
1.4	56906	Ground Floor Sales	CG2	11	0.000	1	CG1	sal						
		Ground Floor Sales	CS	7301	0.177	1	CS	sal						
		Ground Floor Sales	CS10	44921	1.090	1	CS	sal						
		Ground Floor Sales	CS3	23	0.001	1	CS	sal						
		Ground Floor Sales	CS4	31	0.001	1	CS	sal						
		Ground Floor Sales	CS7	4176	0.101	1	CS7	sal						
		Ground Floor Sales	CW	246	0.006	1	CW	sal						
		Ground Floor Sales	MX	197	0.005	1	GENERIC	sal						
0.8	33018	Food Processing Areas	CW	5331	0.129	1	GENERIC	proc						
		Food Processing Areas	IF	27325	0.663	1	GENERIC	proc						
		Food Processing Areas	IF3	363	0.009	1	GENERIC	proc						
0.8	32850	Showroom	CG1	268	0.006	1	GENERIC	showroom						
		Showroom	CG3	16711	0.405	1	GENERIC	showroom						
		Showroom	CO	1207	0.029	1	GENERIC	showroom						
		Showroom	CS	3422	0.083	1	GENERIC	showroom						
		Showroom	CS7	6178	0.150	1	GENERIC	showroom						
		Showroom	CW	2924	0.071	1	GENERIC	showroom						
		Showroom	IF	554	0.013	1	GENERIC	showroom						
		Showroom	IF3	1586	0.038	1	GENERIC	showroom						
0.8	31988	Retail Area	CR	247	0.006	1	GENERIC	sal						
		Retail Area	CR1	73	0.002	1	GENERIC	sal						
		Retail Area	CS	26418	0.641	1	CS	sal						
		Retail Area	CS1	64	0.002	1	CS1	profs						
		Retail Area	CS10	261	0.006	1	GENERIC	sal						
		Retail Area	CS2	20	0.000	1	CS	sal						
		Retail Area	CS3	181	0.004	1	CS	sal						
		Retail Area	CS7	747	0.018	1	CS7	sal						
		Retail Area	CS9	3235	0.078	1	CS	sal						
		Retail Area	CW	563	0.014	1	GENERIC	sal						

		Retail Area	IF	27	0.001	1	GENERIC	sal						
		Retail Area	IF3	79	0.002	1	GENERIC	sal						
		Retail Area	LT1	59	0.001	1	CS	sal						
		Retail Area	MH	14	0.000	1	GENERIC	sal						
0.7	30267	Retail Zone C	CO	233	0.006	1	GENERIC	sal						
		Retail Zone C	CR	1430	0.035	1	GENERIC	sal						
		Retail Zone C	CR1	220	0.005	1	GENERIC	sal						
		Retail Zone C	CS	26187	0.635	1	CS	sal						
		Retail Zone C	CS1	1412	0.034	1	CS1	profs						
		Retail Zone C	CS10	9	0.000	1	GENERIC	sal						
		Retail Zone C	CS2	183	0.004	1	CS	sal						
		Retail Zone C	CS3	99	0.002	1	CS	sal						
		Retail Zone C	CS5	77	0.002	1	GENERIC	sal						
		Retail Zone C	CS6	114	0.003	1	CS6	profs						
		Retail Zone C	CS7	240	0.006	1	CS7	sal						
		Retail Zone C	LT1	50	0.001	1	CS	sal						
		Retail Zone C	MH	13	0.000	1	GENERIC	sal						
0.7	29243	Unsurfaced, fenced land	CW1	29243	0.709	2								
0.6	24227	Hard Surfaced, fenced land	CG1	108	0.003	2								
		Hard Surfaced, fenced land	CW1	20700	0.502	2								
		Hard Surfaced, fenced land	CX	3419	0.083	2								
0.5	22488	Rough surfaced, fenced land	CW1	21710	0.527	2								
		Rough surfaced, fenced land	CX	778	0.019	2								
0.5	22432	Remaining Retail Zone	CO	53	0.001	1	GENERIC	sal						
		Remaining Retail Zone	CR	908	0.022	1	GENERIC	sal						
		Remaining Retail Zone	CR1	16	0.000	1	CS	sal						
		Remaining Retail Zone	CS	20471	0.497	1	CS	sal						
		Remaining Retail Zone	CS1	901	0.022	1	CS1	profs						
		Remaining Retail Zone	CS7	53	0.001	1	CS7	sal						
		Remaining Retail Zone	LT1	31	0.001	1	CS	sal						
0.5	22390	External storage	CG1	180	0.004	2								
		External storage	CG2	171	0.004	2								

		External storage	CG3	232	0.006	2								
		External storage	CL2	161	0.004	2								
		External storage	CO	1256	0.030	2								
		External storage	CR	114	0.003	2								
		External storage	CR1	36	0.001	2								
		External storage	CS	3686	0.089	2								
		External storage	CS1	43	0.001	2								
		External storage	CS2	3	0.000	2								
		External storage	CS3	15	0.000	2								
		External storage	CS7	41	0.001	2								
		External storage	CS9	422	0.010	2								
		External storage	CW	6616	0.160	2								
		External storage	CW2	96	0.002	2								
		External storage	CW3	1119	0.027	2								
		External storage	EN1	125	0.003	2								
		External storage	IF	5637	0.137	2								
		External storage	IF3	1869	0.045	2								
		External storage	LC	390	0.009	2								
		External storage	LC3	13	0.000	2								
		External storage	MH	114	0.003	2								
		External storage	ML	52	0.001	2								
0.5	21198	Works office	CG1	559	0.014	1	CG1	off	prin	mtg	teach	circ		
		Works office	CG2	639	0.015	1	CG1	off	prin	mtg	teach	circ		
		Works office	CG3	819	0.020	1	CG1	off	prin	mtg	teach	circ		
		Works office	CO	350	0.008	1	CO	off	prin	sec	mtg	cmp	teach	
		Works office	CS	111	0.003	1	CS	off	prin	sec	mtg	cmp	teach	circ
		Works office	CW	4415	0.107	1	CW	off	prin	mtg	cmp	teach	circ	
		Works office	CW2	65	0.002	1	CW	off	prin	mtg	cmp	teach	circ	
		Works office	CW3	799	0.019	1	CW	off	prin	mtg	cmp	teach	circ	
		Works office	IF	10694	0.259	1	IF	off	prin	mtg	cmp	teach	circ	graph
		Works office	IF2	120	0.003	1	IF	off	prin	mtg	cmp	teach	circ	
		Works office	IF3	2627	0.064	1	IF3	off	circ	graph	ph			

0.5	19278	Kitchen	CG1	7	0.000	1	IF3	tea						
		Kitchen	CG2	10	0.000	1	IF3	tea						
		Kitchen	CG3	26	0.001	1	IF3	tea						
		Kitchen	CL1	58	0.001	1	CL	cook	servfd	ffc				
		Kitchen	CL2	968	0.023	1	CL	cook	servfd	ffc				
		Kitchen	CO	2575	0.062	1	CO	cook	servfd	ffc	tea			
		Kitchen	CR	3911	0.095	1	CR	cook	servfd	ffc				
		Kitchen	CR1	499	0.012	1	CR	cook	servfd	ffc				
		Kitchen	CS	7343	0.178	1	CS	cook	servfd	ffc	tea			
		Kitchen	CS1	123	0.003	1	CS1	cook	servfd	ffc	tea			
		Kitchen	CS2	128	0.003	1	CS	cook	servfd	ffc	tea			
		Kitchen	CS3	322	0.008	1	CS	cook	servfd	ffc	tea			
		Kitchen	CS4	14	0.000	1	CS	cook	servfd	ffc	tea			
		Kitchen	CS5	9	0.000	1	CS	cook	servfd	ffc	tea			
		Kitchen	CW	258	0.006	1	CW	cook	servfd	ffc				
		Kitchen	CW3	7	0.000	1	CW	cook	servfd	ffc				
		Kitchen	EN1	860	0.021	1	EL	cook	servfd	ffc	tea			
		Kitchen	EP	9	0.000	1	EL	cook	servfd	ffc	tea			
		Kitchen	IF	550	0.013	1	IF	cook	servfd	ffc	tea			
		Kitchen	IF3	133	0.003	1	IF3	cook	servfd	ffc	tea			
		Kitchen	LC	954	0.023	1	LC1	cook	servfd	ffc	tea			
		Kitchen	LC1	68	0.002	1	LC1	cook	servfd	ffc	tea			
		Kitchen	LC3	286	0.007	1	LC1	cook	servfd	ffc	tea			
		Kitchen	LT1	7	0.000	1	CS	cook	servfd	ffc	tea			
		Kitchen	MH	121	0.003	1	CO	cook	servfd	ffc	tea			
		Kitchen	MX	31	0.001	1	CS	cook	servfd	ffc	tea			
0.4	15333	Restaurant	CL1	225	0.005	1	CR	eat						
		Restaurant	CL2	229	0.006	1	CR	eat						
		Restaurant	CO	856	0.021	1	CO	eat						
		Restaurant	CR	12455	0.302	1	CR	eat						
		Restaurant	CR1	192	0.005	1	CR	eat						
		Restaurant	CS	876	0.021	1	CS	eat						

		Restaurant	CW	122	0.003	1	IF	eat						
		Restaurant	IF2	380	0.009	1	IF	eat						
0.4	15195	Loading Bay	CG1	11	0.000	3	GENERIC	loading						
		Loading Bay	CG3	24	0.001	3	GENERIC	loading						
		Loading Bay	CO	106	0.003	3	GENERIC	loading						
		Loading Bay	CR	23	0.001	3	GENERIC	loading						
		Loading Bay	CS	509	0.012	3	GENERIC	loading						
		Loading Bay	CS1	32	0.001	3	GENERIC	loading						
		Loading Bay	CW	6075	0.147	3	GENERIC	loading						
		Loading Bay	CX	24	0.001	3	GENERIC	loading						
		Loading Bay	IF	7980	0.194	3	GENERIC	loading						
		Loading Bay	IF3	411	0.010	3	GENERIC	loading						
0.4	14790	Garage	CG1	1378	0.033	3	CG1	carser						
		Garage	CG2	5874	0.143	3	CG1	carser						
		Garage	CG3	546	0.013	3	CG1	carser						
		Garage	CL2	15	0.000	3	GENERIC	cp						
		Garage	CO	188	0.005	3	GENERIC	cp						
		Garage	CP1	2	0.000	3	GENERIC	cp						
		Garage	CS	563	0.014	3	GENERIC	cp						
		Garage	CW	729	0.018	3	GENERIC	cp						
		Garage	CW2	465	0.011	3	GENERIC	cp						
		Garage	CW3	92	0.002	3	GENERIC	cp						
		Garage	CX	480	0.012	3	GENERIC	cp						
		Garage	IF	2200	0.053	3	GENERIC	cp						
		Garage	IF2	1486	0.036	3	GENERIC	cp						
		Garage	IF3	516	0.013	3	GENERIC	cp						
		Garage	LC	124	0.003	3	GENERIC	cp						
		Garage	LC3	26	0.001	3	GENERIC	cp						
		Garage	ML	108	0.003	3	GENERIC	cp						
0.3	13728	Canopy	CG1	46	0.001	3	GENERIC	canopy						
		Canopy	CG2	39	0.001	3	GENERIC	canopy						
		Canopy	CG3	115	0.003	3	GENERIC	canopy						

		Canopy	CO	16	0.000	3	GENERIC	canopy						
		Canopy	CP	126	0.003	3	GENERIC	canopy						
		Canopy	CS	56	0.001	3	GENERIC	canopy						
		Canopy	CS10	205	0.005	3	GENERIC	canopy						
		Canopy	CW	8434	0.205	3	GENERIC	canopy						
		Canopy	CW1	399	0.010	3	GENERIC	canopy						
		Canopy	CW3	158	0.004	3	GENERIC	canopy						
		Canopy	EN1	296	0.007	3	GENERIC	canopy						
		Canopy	IF	2684	0.065	3	GENERIC	canopy						
		Canopy	IF2	199	0.005	3	GENERIC	canopy						
		Canopy	IF3	958	0.023	3	GENERIC	canopy						
0.3	10389	Plant room	CG3	110	0.003	1	CG1	bse						
		Plant room	CO	244	0.006	1	CO	bse						
		Plant room	CR	0	0.000	1	CR	bse						
		Plant room	CR1	0	0.000	1	CR	bse						
		Plant room	CS	0	0.000	1	CS	bse						
		Plant room	CS1	0	0.000	1	CS	bse						
		Plant room	CS5	0	0.000	1	CS	bse						
		Plant room	CS7	3	0.000	1	GENERIC	bse						
		Plant room	CW	1087	0.026	1	CG1	bse						
		Plant room	CW2	0	0.000	1	CG1	bse						
		Plant room	CW3	904	0.022	1	CG1	bse						
		Plant room	EN1	0	0.000	1	EL	bse						
		Plant room	IF	6102	0.148	1	IF	bse						
		Plant room	IF2	816	0.020	1	IF	bse						
		Plant room	IF3	1012	0.025	1	IF	bse						
		Plant room	LC	94	0.002	1	LC1	bse						
		Plant room	LC1	11	0.000	1	LC1	bse						
		Plant room	LC3	6	0.000	1	LC1	bse						
		Plant room	MH	0	0.000	1	GENERIC	bse						
		Plant room	ML	0	0.000	1	GENERIC	bse						
0.3	10354	Parking Space(s)	CP	9893	0.240	2								

		Parking Space(s)	CP1	461	0.011	2								
0.2	9571	Lounge	CL2	8975	0.218	1	CH	soc						
		Lounge	CO	62	0.001	1	GENERIC	soc						
		Lounge	LC	442	0.011	1	LC1	soc						
		Lounge	LC3	93	0.002	1	LC1	soc						
0.2	7166	Nursery	CO	526	0.013	1	EL	child						
		Nursery	CW	260	0.006	1	EL	child						
		Nursery	EN1	6349	0.154	1	EL	child						
		Nursery	LC	30	0.001	1	EL	child						
0.2	6932	Bar	CL2	2618	0.064	1	GENERIC	drink						
		Bar	CO	12	0.000	1	GENERIC	drink						
		Bar	CR	235	0.006	1	GENERIC	drink						
		Bar	CR1	36	0.001	1	GENERIC	drink						
		Bar	EN1	5	0.000	1	N/A	N/A						
		Bar	IF	3944	0.096	1	N/A	N/A						
		Bar	LC	59	0.001	1	GENERIC	drink						
		Bar	LC1	7	0.000	1	GENERIC	drink						
		Bar	LC3	15	0.000	1	GENERIC	drink						
0.2	6875	Mess/Staff room	CG1	21	0.001	1	CG1	soc	tea					
		Mess/Staff room	CG3	133	0.003	1	CG1	soc	tea					
		Mess/Staff room	CL2	27	0.001	1	LC1	soc	tea					
		Mess/Staff room	CO	261	0.006	1	CO	soc	tea					
		Mess/Staff room	CR	217	0.005	1	CR	soc	tea					
		Mess/Staff room	CR1	48	0.001	1	CR	soc	tea					
		Mess/Staff room	CS	2785	0.068	1	CS	soc	tea					
		Mess/Staff room	CS1	556	0.013	1	CS1	soc	tea					
		Mess/Staff room	CS2	34	0.001	1	CS	soc	tea					
		Mess/Staff room	CS3	183	0.004	1	CS	soc	tea					
		Mess/Staff room	CS7	63	0.002	1	CS	soc	tea					
		Mess/Staff room	CW	123	0.003	1	CW	soc	tea					
		Mess/Staff room	CW3	17	0.000	1	CW	soc	tea					
		Mess/Staff room	EN1	202	0.005	1	EL	soc	tea					

		Mess/Staff room	IF	311	0.008	1	IF	soc	tea					
		Mess/Staff room	IF3	126	0.003	1	IF3	soc	tea					
		Mess/Staff room	IX	1659	0.040	1	IF	soc	tea					
		Mess/Staff room	LC	5	0.000	1	LC1	soc	tea					
		Mess/Staff room	MH	102	0.002	1	CO	soc	tea					
0.1	5546	Canteen	CG2	37	0.001	1	IF	eat						
		Canteen	CG3	206	0.005	1	IF	eat						
		Canteen	CO	536	0.013	1	CO	eat						
		Canteen	CR	69	0.002	1	CR	eat						
		Canteen	CS	84	0.002	1	CS	eat						
		Canteen	CS10	79	0.002	1	CS	eat						
		Canteen	CW	473	0.011	1	CW	eat						
		Canteen	CW2	106	0.003	1	CW	eat						
		Canteen	IF	3543	0.086	1	IF	eat						
		Canteen	IF2	124	0.003	1	IF	eat						
		Canteen	IF3	267	0.006	1	IF	eat						
		Canteen	LC3	23	0.001	1	LC1	eat						
0.1	4838	Storage	CO	182	0.004	1	CO	store	spstore	lib				
		Storage	CS	230	0.006	1	CS	store	spstore					
		Storage	CS10	89	0.002	1	CS	store	spstore					
		Storage	CS7	0	0.000	1	CS	store	spstore					
		Storage	CW	2087	0.051	1	CW	store	spstore					
		Storage	CW3	250	0.006	1	CW	store	spstore					
		Storage	CX	347	0.008	1	GENERIC	store	spstore					
		Storage	EN1	8	0.000	1	EL	store	spstore					
		Storage	IF	1435	0.035	1	IF	store	spstore					
		Storage	IF2	43	0.001	1	IF	store	spstore					
		Storage	IF3	165	0.004	1	IF3	store	spstore					
0.1	4620	Surgery	CO	65	0.002	1	CO	off	wait	prin	mtg			
		Surgery	CS	43	0.001	1	CO	off	wait	prin	mtg			
		Surgery	CS3	22	0.001	1	CO	off	wait	prin	mtg			
		Surgery	CX	32	0.001	1	CO	off	wait	prin	mtg			

		Surgery	MH	4250	0.103	1	CO	off	wait	prin	mtg			
		Surgery	MH1	208	0.005	1	CO	off	wait	prin	mtg			
0.1	3886	Classroom	CO	992	0.024	1	CO	teach						
		Classroom	EN1	1103	0.027	1	EL	teach						
		Classroom	IF	1406	0.034	1	IF	teach						
		Classroom	LC	347	0.008	1	GENERIC	teach						
		Classroom	LC3	38	0.001	1	GENERIC	teach						
0.1	3600	Chill store	CR	3	0.000	1	GENERIC	chill						
		Chill store	CS	5	0.000	1	GENERIC	chill						
		Chill store	CW	3565	0.086	1	GENERIC	chill						
		Chill store	IF	27	0.001	1	GENERIC	chill						
0.1	3544	Ancillary Office	CG1	27	0.001	1	CG1	off	prin	teach	circ			
		Ancillary Office	CG3	66	0.002	1	CG1	off	prin	teach	circ			
		Ancillary Office	CO	245	0.006	1	CO	off	prin	sec	mtg	cmp	teach	
		Ancillary Office	CS	734	0.018	1	CS	off	prin	sec	mtg	cmp	teach	circ
		Ancillary Office	CS7	104	0.003	1	CS7	off	prin	cmp	circ			
		Ancillary Office	CW	1176	0.029	1	CW	off	prin	mtg	cmp	teach	circ	
		Ancillary Office	IF	697	0.017	1	IF	off	prin	mtg	cmp	teach	circ	graph
		Ancillary Office	IF3	275	0.007	1	IF3	off	prin	mtg	circ	graph	ph	
		Ancillary Office	LT1	221	0.005	1	GENERIC	off	sec					
0.1	2364	Public toilets	CG2	0	0.000	1	CG	washp						
		Public toilets	CL1	15	0.000	1	CL	washp						
		Public toilets	CO	37	0.001	1	CO	washp						
		Public toilets	CR	633	0.015	1	CR	washp						
		Public toilets	CR1	89	0.002	1	CR	washp						
		Public toilets	CS	195	0.005	1	CS	washp						
		Public toilets	CS2	14	0.000	1	CS	washp						
		Public toilets	CS3	2	0.000	1	CS	washp						
		Public toilets	CW	39	0.001	1	CW	washp						
		Public toilets	EN1	295	0.007	1	EL	washp						
		Public toilets	IF3	1	0.000	1	IF3	washp						
		Public toilets	LC	598	0.015	1	LC1	washp						

		Public toilets	LC1	56	0.001	1	LC1	washp						
		Public toilets	LC3	352	0.009	1	LC1	washp						
		Public toilets	MH	38	0.001	1	CO	washp						
0.1	2290	Reception / Entrance	CG1	20	0.000	1	CO	recep						
		Reception / Entrance	CG3	34	0.001	1	CO	recep						
		Reception / Entrance	CL2	39	0.001	1	LC1	recep						
		Reception / Entrance	CO	861	0.021	1	CO	recep						
		Reception / Entrance	CR	32	0.001	1	CR	recep						
		Reception / Entrance	CS	125	0.003	1	CS	recep						
		Reception / Entrance	CS1	15	0.000	1	CS1	recep						
		Reception / Entrance	CS3	0	0.000	1	CS	recep						
		Reception / Entrance	CW	76	0.002	1	CW	recep						
		Reception / Entrance	CW3	35	0.001	1	CW	recep						
		Reception / Entrance	CX	32	0.001	1	GENERIC	recep						
		Reception / Entrance	EN1	161	0.004	1	EL	recep						
		Reception / Entrance	IF	192	0.005	1	IF	recep						
		Reception / Entrance	IF3	75	0.002	1	IF3	recep						
		Reception / Entrance	LC	175	0.004	1	LC1	recep						
		Reception / Entrance	LC1	8	0.000	1	LC1	recep						
		Reception / Entrance	LC3	63	0.002	1	LC1	recep						
		Reception / Entrance	MH	348	0.008	1	CO	recep						
0.0	1546	Cold store	CR	155	0.004	1	GENERIC	froz						
		Cold store	CS	459	0.011	1	GENERIC	froz						
		Cold store	CS4	3	0.000	1	GENERIC	froz						
		Cold store	CW	206	0.005	1	GENERIC	froz						
		Cold store	CW2	137	0.003	1	GENERIC	froz						
		Cold store	CW3	156	0.004	1	GENERIC	froz						
		Cold store	IF	431	0.010	1	GENERIC	froz						
0.0	1506	Unclassified area	CO	198	0.005	4								
		Unclassified area	CS	92	0.002	4								
		Unclassified area	CS1	1087	0.026	4								
		Unclassified area	CW	116	0.003	4								

		Unclassified area	ML	12	0.000	4								
0.0	1484	Hard Surfaced, unfenced land	CW1	1484	0.036	2								
0.0	1300	Unsurfaced, unfenced land	CW1	1300	0.032	2								
0.0	1243	Shed	CG2	113	0.003	3	CW	store						
		Shed	CO	110	0.003	3	CW	store						
		Shed	CS	71	0.002	3	CW	store						
		Shed	CW	644	0.016	3	CW	store						
		Shed	CW3	42	0.001	3	CW	store						
		Shed	EN1	30	0.001	3	CW	store						
		Shed	IF	232	0.006	3	CW	store						
0.0	1226	Function Room	CR	256	0.006	1	LC1	danc	eat	assem	soc			
		Function Room	LC	970	0.024	1	LC1	danc	eat	assem	soc			
0.0	1098	Staff toilets	CG1	10	0.000	1	CG1	washp						
		Staff toilets	CG3	22	0.001	1	CG1	washp						
		Staff toilets	CL1	0	0.000	1	CL	washp						
		Staff toilets	CL2	0	0.000	1	CL	washp						
		Staff toilets	CO	0	0.000	1	CO	washp						
		Staff toilets	CR	0	0.000	1	CR	washp						
		Staff toilets	CR1	0	0.000	1	CR	washp						
		Staff toilets	CS	3	0.000	1	CS	washp						
		Staff toilets	CS1	0	0.000	1	CS1	washp						
		Staff toilets	CS10	0	0.000	1	CS	washp						
		Staff toilets	CS2	0	0.000	1	CS	washp						
		Staff toilets	CS3	0	0.000	1	CS	washp						
		Staff toilets	CS5	0	0.000	1	CS	washp						
		Staff toilets	CS7	0	0.000	1	CS7	washp						
		Staff toilets	CW	196	0.005	1	CW	washp						
		Staff toilets	CW3	0	0.000	1	GENERIC	washp						
		Staff toilets	CX	0	0.000	1	GENERIC	washp						
		Staff toilets	EN1	0	0.000	1	EL	washp						
		Staff toilets	IF	629	0.015	1	IF	washp						
		Staff toilets	IF3	120	0.003	1	IF3	washp						

		Staff toilets	LC	101	0.002	1	LC1	washp						
		Staff toilets	LC3	17	0.000	1	LC1	washp						
		Staff toilets	LT1	0	0.000	1	GENERIC	washp						
		Staff toilets	MH	0	0.000	1	CO	washp						
0.0	879	Changing room	CL2	162	0.004	1	CL	washp						
		Changing room	CS	69	0.002	1	CS	washp						
		Changing room	CS3	3	0.000	1	CS	washp						
		Changing room	EN1	17	0.000	1	EL	washp						
		Changing room	EP	51	0.001	1	EL	washp						
		Changing room	IF	95	0.002	1	IF	washp						
		Changing room	LC	235	0.006	1	LC1	washp						
		Changing room	LC1	139	0.003	1	LC1	washp						
		Changing room	LC3	98	0.002	1	LC1	washp						
		Changing room	LX	10	0.000	1	LC1	washp						
0.0	855	Computer room	CO	290	0.007	1	CO	cmp						
		Computer room	CS	7	0.000	1	CS	cmp						
		Computer room	CS1	35	0.001	1	CS1	cmp						
		Computer room	IF	432	0.010	1	IF	cmp						
		Computer room	LC	92	0.002	1	CO	off						
0.0	721	Banking Hall	CS1	721	0.017	1	CS1	profs						
0.0	699	Locker room	CL2	64	0.002	1	CL	washp						
		Locker room	CO	377	0.009	1	CO	washp						
		Locker room	CR	11	0.000	1	CR	washp						
		Locker room	CS	82	0.002	1	CS	washp						
		Locker room	CS1	12	0.000	1	CS1	washp						
		Locker room	EP	12	0.000	1	EL	washp						
		Locker room	IF	129	0.003	1	IF	washp						
		Locker room	LC	8	0.000	1	LC1	washp						
		Locker room	LC3	4	0.000	1	LC1	washp						
0.0	629	Committee Room	CL2	487	0.012	1	EL	mtg						
		Committee Room	CO	26	0.001	1	CO	mtg						
		Committee Room	LC	15	0.000	1	EL	mtg						

		Committee Room	LC3	101	0.002	1	EL	mtg						
0.0	624	Laboratory	CO	74	0.002	1	GENERIC	proc						
		Laboratory	CW	291	0.007	1	GENERIC	proc						
		Laboratory	IF	224	0.005	1	GENERIC	proc						
		Laboratory	IF2	21	0.001	1	GENERIC	proc						
		Laboratory	MH	14	0.000	1	GENERIC	proc						
0.0	366	Covered Area	CS	20	0.000	3								
		Covered Area	EN1	0	0.000	3								
		Covered Area	IF	169	0.004	3								
		Covered Area	IF3	16	0.000	3								
		Covered Area	LC	161	0.004	3								
0.0	290	Cells	CO	290	0.007	1	CO	store						
0.0	248	Health Centre	MH	248	0.006	1	CO	GENERIC						
0.0	225	Gatehouse	CS10	12	0.000	1	CS	off	sec					
		Gatehouse	CW	31	0.001	1	CW	off						
		Gatehouse	CW3	54	0.001	1	CW	off						
		Gatehouse	IF	128	0.003	1	IF	off						
0.0	213	Portable Building	CL2	43	0.001	1	CR	off						
		Portable Building	CO	170	0.004	1	CO	off	prin	sec				
0.0	143	Canopy/Loading Dock	CW	143	0.003	3	GENERIC	canopy						
0.0	123	Atrium	CO	123	0.003	1	CO	circ						
0.0	122	Showers	LC	30	0.001	1	LC1	washp						
		Showers	LC1	71	0.002	1	LC1	washp						
		Showers	LC3	21	0.000	1	LC1	washp						
		Showers	MH	0	0.000	1	CO	washp						
0.0	78	Lock Up Garage	CG1	44	0.001	3								
		Lock Up Garage	CW3	35	0.001	3								
0.0	35	First floor sales	CS	35	0.001	1	CS	sal						
0.0	30	Retail Zone D	CS1	30	0.001	1	CS1	profs						
0.0	28	Boardroom	CO	28	0.001	1	CO	mtg						
0.0	14	Glasshouse	CX	14	0.000	3								
0.0	10	Strongroom	CS	10	0.000	1	CS1	spstore						

0.0	0	Lift Shaft	CS	0	0.000	1	CS	bse						
	0	Lift Shaft	CS1	0	0.000	1	CS1	bse						
1.0	39836	Hall	CL2	8293	0.201	1	LC1	danc	eat	assem	soc			
		Hall	CO	4631	0.112	1	EL	assem						
		Hall	CS	93	0.002	1	EL	assem						
		Hall	CW	1105	0.027	1	GENERIC	rec						
		Hall	IF	2313	0.056	1	IF	proc						
		Hall	IF2	2015	0.049	1	IF	proc						
		Hall	LC	13916	0.338	1	EL	assem	soc					
		Hall	LC1	1096	0.027	1	LC1	danc	eat	assem	soc			
		Hall	LC3	6375	0.155	1	EL	assem						
0.5	19554	_shop	CG1	320	0.008	1	CG1	carser						
		_shop	CG3	62	0.002	1	CG1	sal						
		_shop	CO	659	0.016	1	CS	sal						
		_shop	CR	28	0.001	1	CS	sal						
		_shop	CR1	217	0.005	1	CR	eat						
		_shop	CS	101	0.002	1	CS	sal						
		_shop	IF	13176	0.320	1	IF	proc						
		_shop	IF2	4806	0.117	1	IF	proc						
		_shop	IF3	113	0.003	1	IF3	proc						
		_shop	ML	73	0.002	1	CS	sal						
0.3	12911	Vehicle Repair Workshop	CG1	9587	0.233	1	CG1	carser						
		Vehicle Repair Workshop	CG2	950	0.023	1	CG1	carser						
		Vehicle Repair Workshop	CW	361	0.009	1	CG1	carser						
		Vehicle Repair Workshop	CW3	52	0.001	1	CG1	carser						
		Vehicle Repair Workshop	IF	39	0.001	1	CG1	carser						
		Vehicle Repair Workshop	IF3	1921	0.047	1	CG1	carser						
0.3	12270	_Land	CW1	4660	0.113	2								
		_Land	CX	7610	0.185	2								
0.2	9424	Sales floor	CS	927	0.022	1	CS	sal						
		Sales floor	CS10	8498	0.206	1	CS	sal						
0.2	8894	Assembly	CS	162	0.004	1	EL	assem						

		Assembly	IF	8732	0.212	1	IF	proc						
0.2	8071	Retail warehouse	CS	328	0.008	1	CS	sal						
		Retail warehouse	CS10	7070	0.172	1	CS	GENERIC						
		Retail warehouse	CS7	672	0.016	1	CS7	sal						
0.2	7653	Sorting Office	CW	1007	0.024	1	CW	deldes						
		Sorting Office	IX	6646	0.161	1	CW	deldes						
0.2	6447	Studio	CO	1104	0.027	1	CO	off	graph	ph	aud	art		
		Studio	CS	150	0.004	1	CS	worksh	sal					
		Studio	CW	163	0.004	1	CW	off	sal					
		Studio	CW3	298	0.007	1	CO	off						
		Studio	CX	545	0.013	1	CO	off	graph	ph	aud	art		
		Studio	EP	2149	0.052	1	GENERIC	danc						
		Studio	IF	72	0.002	1	IF	graph	off					
		Studio	IF3	1965	0.048	1	GENERIC	graph	off					
0.1	5664	Packing	CS	22	0.001	1	CS	deldes						
		Packing	CW	3309	0.080	1	IF	proc						
		Packing	IF	2333	0.057	1	IF	proc						
0.1	5096	Billiard/Pool/Snooker Hall/Room	CL2	4141	0.100	1	LC1	rec	soc					
		Billiard/Pool/Snooker Hall/Room	CW	642	0.016	1	LC1	rec	soc					
		Billiard/Pool/Snooker Hall/Room	LC	34	0.001	1	LC1	rec	soc					
		Billiard/Pool/Snooker Hall/Room	LC3	27	0.001	1	LC1	rec	soc					
		Billiard/Pool/Snooker Hall/Room	LX	253	0.006	1	LC1	rec	soc					
0.1	5050	Compound	CW1	5050	0.123	2								
0.1	4538	Community	CO	470	0.011	1	GENERIC	soc						
		Community	CS7	407	0.010	1	GENERIC	soc						
		Community	CW	114	0.003	1	GENERIC	soc						
		Community	IF	341	0.008	1	GENERIC	soc						
		Community	LC	2840	0.069	1	GENERIC	soc						
		Community	LC3	365	0.009	1	GENERIC	soc						
0.1	4499	Surgeries	MH	4499	0.109	1	CO	off	wait					
0.1	4159	Club	CL2	615	0.015	1	LC1	danc	soc					
		Club	CO	603	0.015	1	CO	soc						

		Club	CS	62	0.002	1	CS	soc						
		Club	IF	1192	0.029	1	LC1	danc	soc					
		Club	LC	1366	0.033	1	LC1	danc	soc					
		Club	LC1	147	0.004	1	LC1	danc	soc					
		Club	LX	175	0.004	1	EL	assem	sport					
0.1	3728	Consulting	CO	345	0.008	1	CO	off	wait					
		Consulting	CR1	94	0.002	1	CO	off	wait					
		Consulting	CS	396	0.010	1	CS	sal						
		Consulting	CS3	6	0.000	1	CS	sal						
		Consulting	MH	2577	0.063	1	CO	off	wait					
		Consulting	MH1	309	0.007	1	CO	off	wait					
0.1	3608	Scrapyard	CW1	3608	0.088	2								
0.1	3592	_site	CX	3592	0.087	2								
0.1	3581	sales etc overall	CS10	3581	0.087	1	CS	GENERIC						
0.1	2843	Cellar	CG2	41	0.001	1	CG1	store	spstore					
		Cellar	CL2	1280	0.031	1	CL	store	spstore					
		Cellar	CO	487	0.012	1	CO	store	spstore	lib				
		Cellar	CR	102	0.002	1	CR	store	spstore					
		Cellar	CR1	58	0.001	1	CR	store	spstore					
		Cellar	CS	703	0.017	1	CS	store	spstore					
		Cellar	CS3	83	0.002	1	CS	store	spstore					
		Cellar	IF3	0	0.000	1	IF3	store	spstore					
		Cellar	LC	26	0.001	1	LC1	store	spstore					
		Cellar	MH	63	0.002	1	CO	store	spstore	lib				
0.1	2710	Garden centre	CS10	2710	0.066	1	GENERIC	canopy						
0.1	2582	Call Centre	CO	2582	0.063	1	CO	callcentre						
0.1	2358	Salon	CO	1276	0.031	1	CS	sal						
		Salon	CS	299	0.007	1	CS	sal						
		Salon	CS3	784	0.019	1	CS	sal						
0.1	2357	Reception	CG3	533	0.013	1	CG1	off						
		Reception	CO	389	0.009	1	CO	recep						
		Reception	CS	83	0.002	1	CS	recep						

		Reception	CS3	46	0.001	1	CS	recep						
		Reception	CW	444	0.011	1	CW	recep						
		Reception	CX	35	0.001	1	GENERIC	recep						
		Reception	EN1	201	0.005	1	EL	recep						
		Reception	IF	111	0.003	1	IF	recep						
		Reception	IF3	4	0.000	1	IF3	recep						
		Reception	MH	511	0.012	1	CO	recep						
0.1	2182	training	CO	889	0.022	1	CO	teach						
		training	CS	167	0.004	1	CS	teach						
		training	CW	264	0.006	1	CW	teach						
		training	EN1	194	0.005	1	EL	teach						
		training	IF	368	0.009	1	IF	teach						
		training	LC1	36	0.001	1	GENERIC	teach						
		training	MX	266	0.006	1	GENERIC	teach						
0.1	2123	Meeting room	CO	576	0.014	1	CO	mtg						
		Meeting room	CX	110	0.003	1	GENERIC	mtg						
		Meeting room	EN1	121	0.003	1	EL	mtg						
		Meeting room	IF	273	0.007	1	IF	mtg						
		Meeting room	LC	979	0.024	1	LC1	mtg						
		Meeting room	LC3	43	0.001	1	LC1	mtg						
		Meeting room	LX	21	0.001	1	GENERIC	mtg						
0.0	2028	Workshop studio	IF3	2028	0.049	1	IF3	proc	off					
0.0	1990	Yard	CG1	29	0.001	2								
		Yard	CS	277	0.007	2								
		Yard	CW	309	0.007	2								
		Yard	CW1	836	0.020	2								
		Yard	CW3	242	0.006	2								
		Yard	IF	258	0.006	2								
		Yard	IF3	39	0.001	2								
0.0	1810	Games room	CL2	1696	0.041	1	GENERIC	rec						
		Games room	CR1	18	0.000	1	GENERIC	rec						
		Games room	LC	97	0.002	1	GENERIC	rec						

0.0	1762	gymnasium	CL2	199	0.005	1	LC1	sport							
		gymnasium	CO	759	0.018	1	LC1	sport							
		gymnasium	CS	48	0.001	1	LC1	sport							
		gymnasium	IF3	347	0.008	1	LC1	sport							
		gymnasium	LX	410	0.010	1	LC1	sport							
0.0	1724	Cafe	CL2	69	0.002	1	LC1	eat	cook						
		Cafe	CO	143	0.003	1	CO	eat	cook						
		Cafe	CR	136	0.003	1	CR	eat							
		Cafe	CR1	1224	0.030	1	CR	eat	cook						
		Cafe	EN1	73	0.002	1	CO	eat	cook						
		Cafe	MX	79	0.002	1	CR	eat	cook						
0.0	1667	Sales area	CR1	27	0.001	1	CS	sal							
		Sales area	CS	1380	0.033	1	CS	sal							
		Sales area	CW	247	0.006	1	CW	sal							
		Sales area	MH	13	0.000	1	GENERIC	sal							
0.0	1555	Vehicle service	CG1	1555	0.038	1	CG1	carser							
0.0	1538	Bodyshop	CG3	1538	0.037	1	CG1	carser							
0.0	1497	Dance Studio	CO	559	0.014	1	GENERIC	danc							
		Dance Studio	EP	658	0.016	1	GENERIC	danc							
		Dance Studio	LC	280	0.007	1	GENERIC	danc							
0.0	1453	Foundry	IF	1453	0.035	1	IF	proc							
0.0	1258	Boiler	CG1	20	0.000	1	CG1	bse							
		Boiler	CL2	20	0.000	1	CR	bse							
		Boiler	CO	3	0.000	1	CO	bse							
		Boiler	CR	0	0.000	1	CR	bse							
		Boiler	CS	0	0.000	1	CS	bse							
		Boiler	CS1	0	0.000	1	CS1	bse							
		Boiler	CS5	0	0.000	1	CS5	bse							
		Boiler	CW	12	0.000	1	CW	bse							
		Boiler	EN1	0	0.000	1	EL	bse							
		Boiler	IF	711	0.017	1	IF	bse							
		Boiler	IF3	51	0.001	1	IF	bse							

		Boiler	LC	390	0.009	1	LC1	bse							
		Boiler	LC3	44	0.001	1	LC1	bse							
		Boiler	MH	8	0.000	1	CO	bse							
		Boiler	ML	0	0.000	1	CO	bse							
0.0	1211	Playroom	CO	77	0.002	1	EL	child							
		Playroom	EN1	894	0.022	1	EL	child							
		Playroom	IF3	114	0.003	1	EL	child							
		Playroom	LC	126	0.003	1	EL	child							
0.0	1076	Printing	IF	721	0.017	1	IF	proc							
		Printing	IF3	355	0.009	1	IF3	proc							
0.0	1069	Bakery	CS	70	0.002	1	CS	cfm							
		Bakery	IF	999	0.024	1	CS	cfm							
0.0	1040	Treatment room	CO	106	0.003	1	CS	sal							
		Treatment room	CS	201	0.005	1	CS	sal							
		Treatment room	CS3	180	0.004	1	CS	sal							
		Treatment room	CX	108	0.003	1	CS	sal							
		Treatment room	MH	445	0.011	1	CO	off							
0.0	994	valeting	CG1	100	0.002	1	CG1	carser							
		valeting	CG2	33	0.001	1	CG1	carser							
		valeting	CG3	861	0.021	1	CG1	carser							
0.0	954	process	IF	954	0.023	1	IF	proc							
0.0	935	service bay	CG1	596	0.014	1	CG1	carser							
		service bay	CG3	287	0.007	1	CG1	carser							
		service bay	CS	51	0.001	1	CG1	carser							
0.0	900	conference	CO	900	0.022	1	CH	assem	soc	circ					
0.0	803	tyre	CG1	537	0.013	1	CG1	carser							
		tyre	CG3	266	0.006	1	CG1	carser							
0.0	773	fitness	CO	190	0.005	1	LC1	sport							
		fitness	CS	33	0.001	1	LC1	sport							
		fitness	CW	290	0.007	1	LC1	sport							
		fitness	LX	261	0.006	1	LC1	sport							
0.0	728	stock room	CS	499	0.012	1	CS	store							

		stock room	CW	230	0.006	1	CW	store						
0.0	711	Production	IF	711	0.017	1	IF	proc						
0.0	698	teaching	CO	542	0.013	1	CO	teach						
		teaching	LC	156	0.004	1	GENERIC	teach						
0.0	635	_production	IF	635	0.015	1	IF	proc						
0.0	590	Lecture	CO	590	0.014	1	EL	teach						
0.0	498	Computer room/Server room	CO	81	0.002	1	CO	cmp						
		Computer room/Server room	IF2	416	0.010	1	IF	cmp						
0.0	441	prod.	IF	441	0.011	1	IF	proc						
0.0	174	Beer cellar	CL1	8	0.000	1	CL	chill						
		Beer cellar	CR	48	0.001	1	CL	chill						
		Beer cellar	CR1	15	0.000	1	CL	chill						
		Beer cellar	CS	104	0.003	1	CL	chill						
0.0	39	External	CS	39	0.001	2								
0.0	0	Lift motor	CS	0	0.000	1	CS	bse						